Appendix B

HYDRAULIC AND SEDIMENT TRANSPORT ANALYSIS AND MODELING

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Hydraulic and Sediment Transport Analysis and Modeling for Savage Rapids Dam Sediment Study

Introduction

This report provides documentation for the analysis and modeling of the sediment impacts on the Rogue River that would result from the potential removal of Savage Rapids Dam, located 5 miles upstream from Grants Pass, Oregon (figure 1). A conceptual model of the Rogue River was developed during and after data collection. Formulating a conceptual model helps in understanding the natural processes of the Rogue River and how these natural processes will be affected by the removal of Savage Rapids Dam. Next, field data were collected in Savage Rapids Reservoir and in the 12.5-mile river reach downstream from Savage Rapids Dam to the confluence with the Applegate River. For the analysis, hydraulic and sedimentation models were used to estimate the expected rate at which reservoir sediments would be eroded and transported downstream following a dam removal and the location and magnitude of deposition that might result downstream from the damsite. In addition, the hydraulic properties at the dam site and the potential sediment impacts to downstream water intake infrastructures following dam removal were evaluated.

Data Collection

Hydraulics and Sedimentation Study Reach

The Rogue River is a relatively steep, gravel- and cobble-bed river consisting of a series of pools, riffles, and rapids. For the hydraulics and sedimentation study, the modeled reach extends from the upstream boundary of the full Savage Rapids Reservoir pool (river mile [RM] 110.6) to the confluence with the Applegate River (RM 95)12.5 miles downstream from Savage Rapids Dam (RM 107.6). (See figure 2.) In the 12.5-mile reach downstream from the dam, the drop in channel bed is nearly 100 feet. Eight of the river pools that exist between Savage Rapids Dam and the confluence with the Applegate River are 10-20 feet deep, but most are shallow pools followed by steep riffles or rapids.

Observations in the field noted that there is a large, unmeasured influx of sediment at the confluence with the Applegate River. The Applegate River was chosen as the downstream boundary because it would be nearly impossible to distinguish the transport of sediment eroded from an upstream dam removal versus the influx of sediment from the Applegate River. Also, the sediment transport capacity of the Rogue River increases downstream from the confluence through Hellgate Canyon.

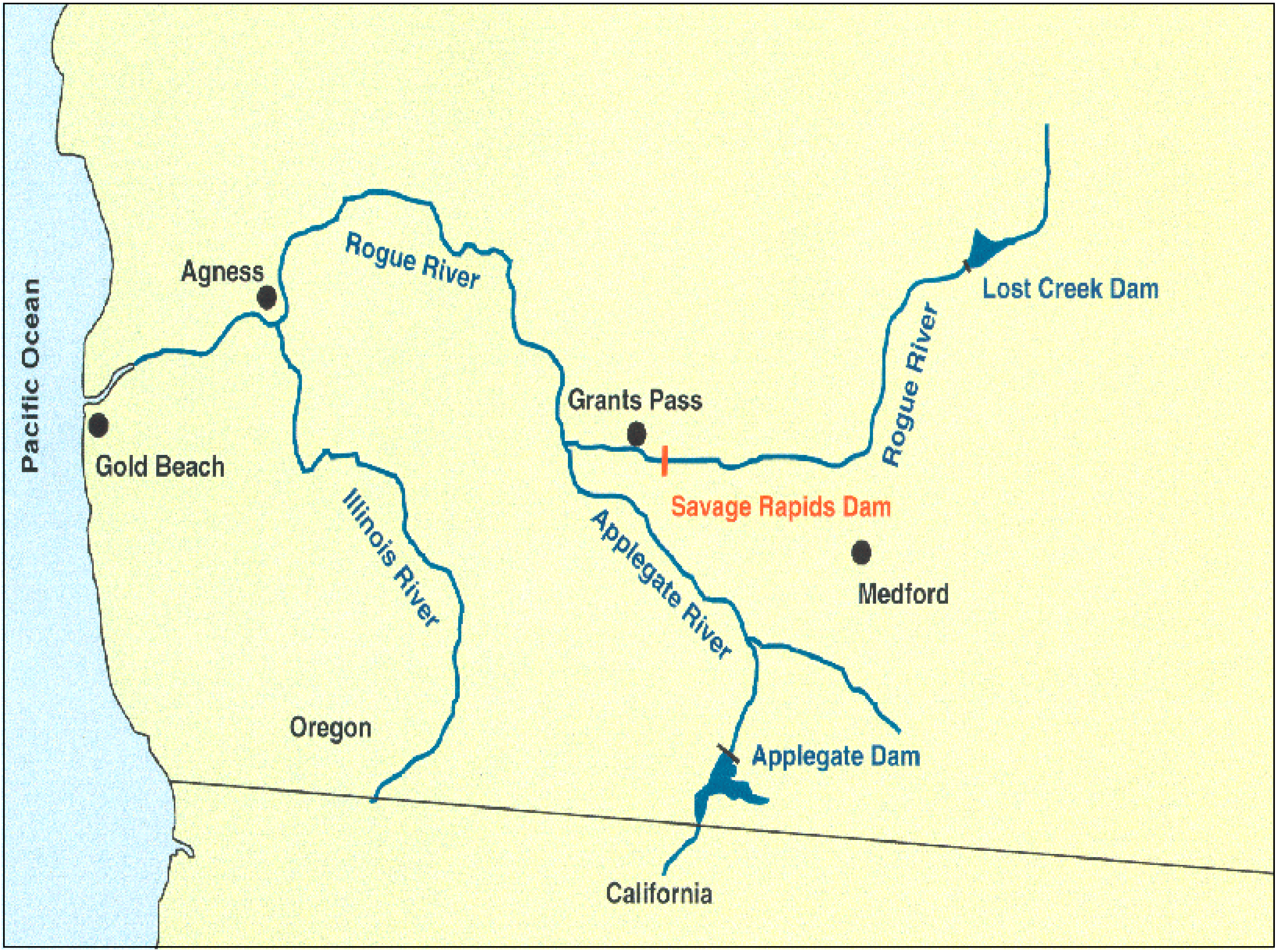

Figure 1.—Savage Rapids Dam is located on the Rogue River in Oregon, 5 miles upstream from the town of Grants Pass.

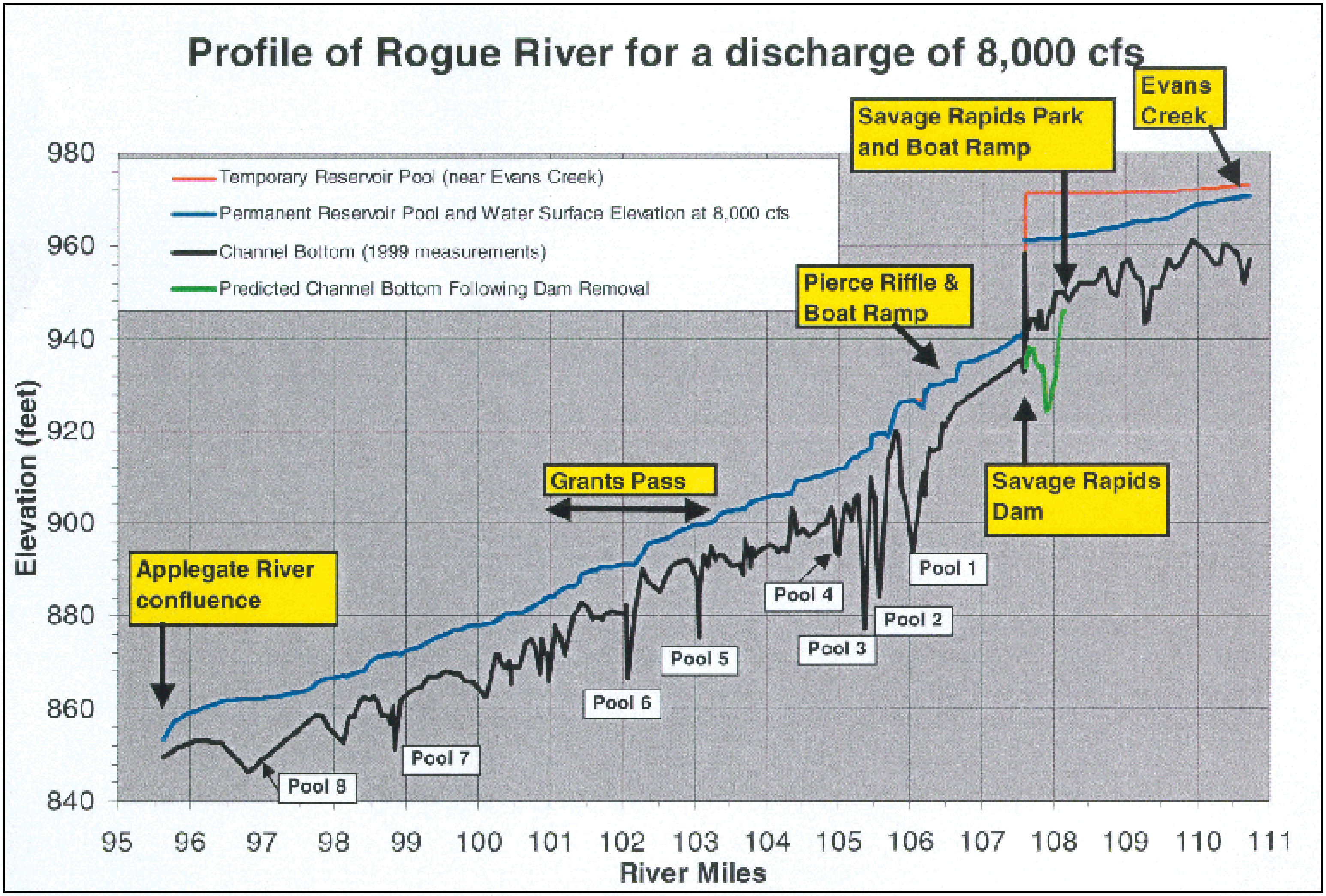

Figure 2.—The Rogue River is a steep, gravel- and cobble-bed river consisting of a series of pools, riffles, and rapids. This profile represents the reach of river from the upstream end of the full Savage Rapids Reservoir pool (RM 110.6) to the confluence with the Applegate River, 12.5 miles downstream from Savage Rapids Dam. The full reservoir pool (shown in red) exists during the irrigation season when stoplogs are used to raise the water surface elevation of the reservoir 11 feet. This extends the backwater pool from ½ mile (near the public boat ramp) to nearly 3 miles at the confluence with Evans Creek.

Sediment Transport Capacity

Sediments that are transported past the confluence with the Applegate River would be transported all the way to the Pacific Ocean, another 95 miles downstream (see figure 1). The slope of the Rogue River is generally steep, but the river slope is less steep in the reach between Grants Pass, Oregon, and the head of Hellgate Canyon (figure 3). The river slope remains steep through Hellgate Canyon, where it averages 0.0024. Just downstream from the mouth of Hellgate Canyon, the slope of the Rogue River flattens out to an average of 0.0008, which would typically reduce sediment transport capacity. However, tributary flows from the Illinois River maintain the river's capacity to transport sediment at a relatively high level. The high transport capacity of the Rogue can be illustrated by looking at the total stream power of the river (water discharge multiplied by channel slope) (figure 4). Because the stream power is higher everywhere downstream from the Applegate River confluence (RM 95 to 0) than between Savage Rapids Dam and the Applegate River (RM 107.6 to 95), any sediments that get transported past the Applegate River will eventually get transported to the Pacific Ocean.

Savage Rapids Reservoir Cross Sections

The Bureau of Reclamation (Reclamation) completed a bathymetric survey of Savage Rapids Reservoir in July 1999 (see map in attachment A). The survey extends from the dam (RM 107.6) upstream to the confluence with Evans Creek (RM 110.6). The survey was performed from a cataraft equipped with global positioning system (GPS) and depth-sounding equipment (figure 5). The channel depths measured in the reservoir were converted to channel bottom elevations by subtracting the depths from the corresponding measured water surface elevations. A 2-foot contour map was then produced for the reservoir bottom using the survey data (see attachment B).

Using the bathymetric data, cross sections were interpreted in the 3,000-foot-long permanent reservoir pool. These cross sections (labeled A through T) were used in the hydraulic and sedimentation model as input data (see attachment A). Additional cross sections were developed in the temporary pool to extend the model another 2.5 miles upstream to the confluence with Evans Creek. Immediately upstream from the dam, several areas of bedrock exist along the left side (looking downstream), and data could not be collected because of safety and access concerns. For this area, a contour map developed for proposed rehabilitation of the dam was used to interpret channel bottom elevations (Reclamation, 1997).

Rogue River Cross Sections Downstream from Savage Rapids Dam to the Applegate River

Survey data of the Rogue River channel bottom were needed downstream from Savage Rapids Dam to document the existing river channel conditions. At the start of the study,

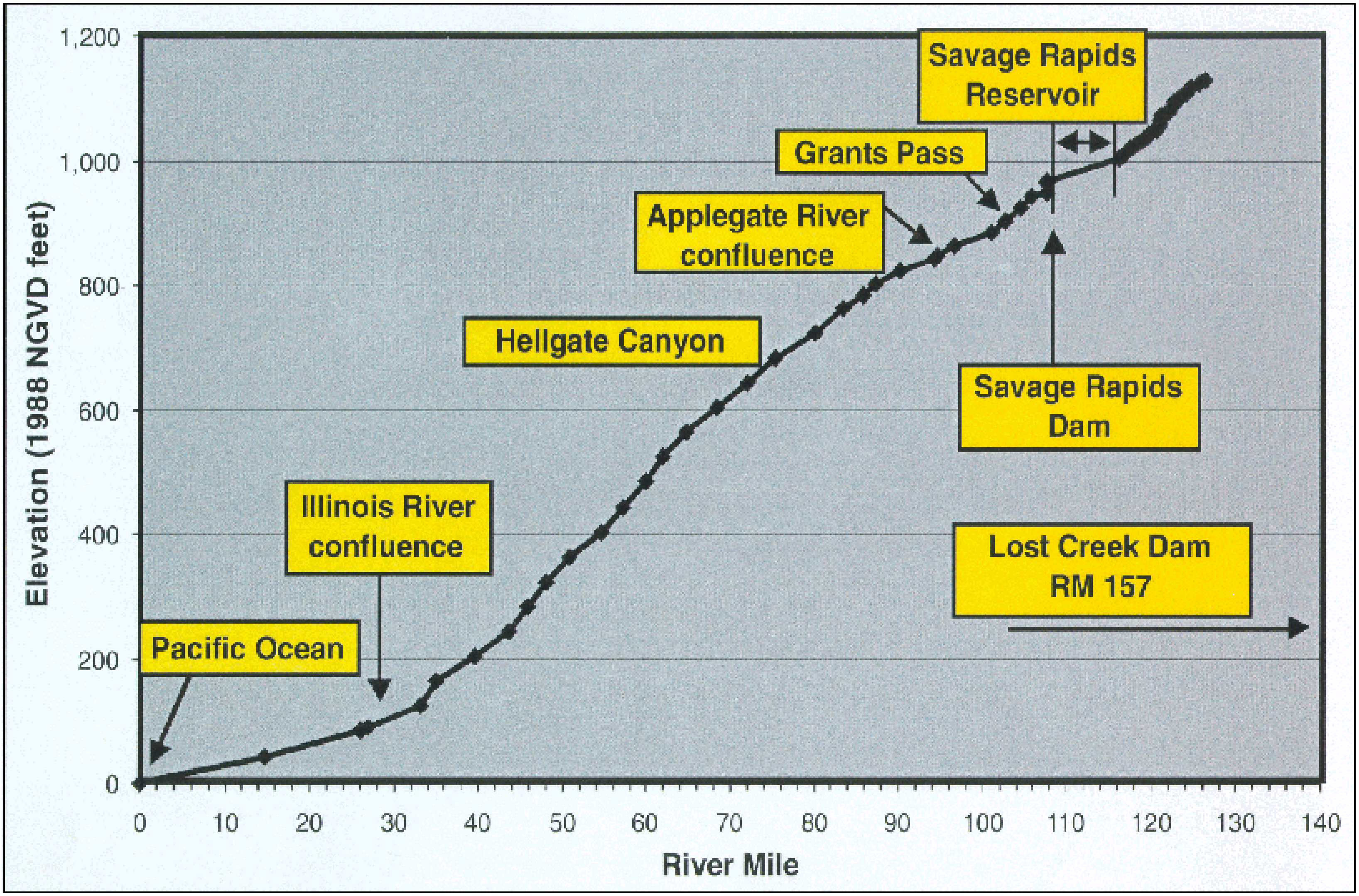

Figure 3.—A longitudinal profile shows the increase in slope downstream from the Applegate River confluence as the Rogue River passes through Hellgate Canyon. In the 30-mile river reach from the mouth of the canyon to the Pacific Ocean, the slope of the Rogue River flattens out.

study, a set of data from a 1991 Flood

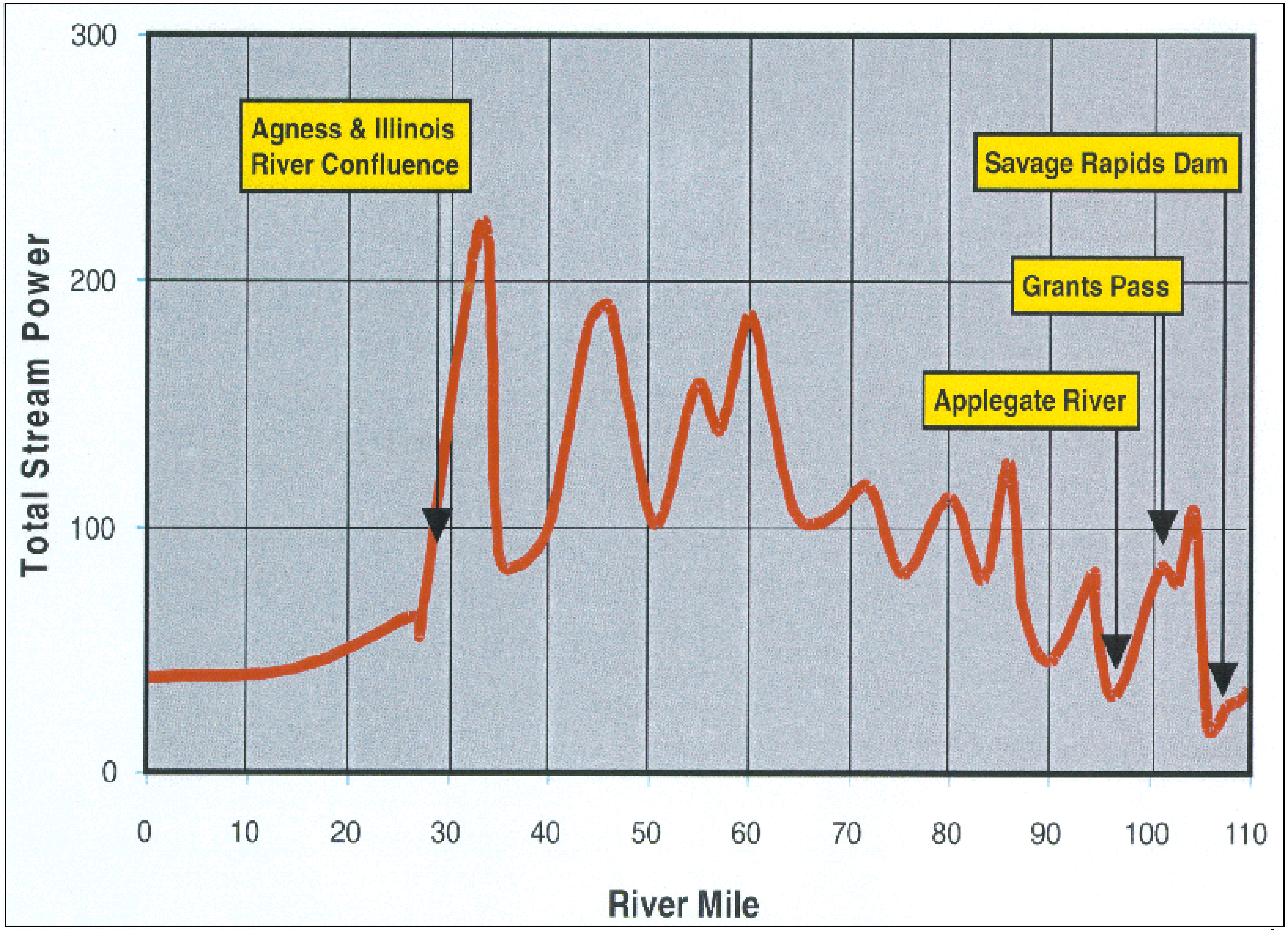

Figure 4.—Total stream power is an indicator of the sediment transport capacity on the Rogue River. Total stream power is computed by multiplying discharge by channel slope.

Figure 5.—A cataraft equipped with GPS survey equipment and a depth sounder was used to survey Savage Rapids Reservoir and the river bottom downstream from the dam to the Applegate River (12 miles).

a set of data from a 1991 Flood Insurance Study was known to exist that provided cross sections perpendicular to the flow from the dam site downstream to the confluence with the Applegate River. To supplement this data, hydrographic data defining the water surface and channel bottom were collected in July 1999 from Pierce Riffle (1 mile downstream from the dam at RM 106.5) to the confluence with the Applegate River (RM 95).

For the first mile downstream from Savage Rapids Dam, the water is shallow and turbulent and has limited boat access. For this reason, survey data were not collected in this reach. However, water surface elevations just downstream from the dam and at the top and bottom of Pierce Riffle were collected to approximate the channel slope in this reach and the drop through Pierce Riffle. Pierce Riffle, surveyed on June 7, 2000, has a measured drop in water surface elevation of 5 feet (discharge of 3,560 cubic feet per second [ft^3/s]).

To perform the survey, a boat ramp just downstream from Pierce Riffle was used to launch a cataraft equipped with a depth sounder and GPS survey equipment. The depth sounder records the channel depth at the same time the GPS equipment records the water surface elevation and horizontal position of each measurement. Because of the high banks and vegetative cover on either side of the channel, it would be difficult to run cross section lines from the boat and maintain a GPS signal (to satellites in the sky) along the shorelines of the river. Even by staying in the center of the channel, a GPS signal lock could not be maintained near the bridges at Grant's Pass. Instead of using GPS, traditional total station surveying could be combined with the sonar measurements on the survey boat, but it would be very time consuming to clear vegetation and difficult to obtain property access permission. Instead, a longitudinal profile along the deepest part of the channel (thalweg) was run with the cataraft to record the water surface and channel bottom slope. These data were to be combined with the U.S. Army Corps of Engineers (Corps) and Federal Emergency Management Agency (FEMA) cross section data.

Unfortunately, after careful evaluation of the available river cross section data, it was determined that the data could not be used because it was outdated, poorly documented, and contained little detail in the study reach. The cross sections were surveyed in 1979 for a Flood Insurance Study by the FEMA. The cross sections were provided in HEC-2 format, a hydraulic computer program developed by the Corps. In addition, longitudinal plots of both channel bottom and water surface profiles were provided as part of the FEMA report.

Both sets of FEMA channel bottom elevation data were plotted against the Reclamation channel bottom and water surface elevations measured in 1999 to determine if the FEMA data were feasible to use (figure 6). While the average slope of the river channel was similar, in many places the old channel bottom measurements plotted above the existing water surface, and riffles were located on top of pools. Although one possible explanation is that the channel bottom may have changed, it is more likely that there is a problem in matching up the locations of the data sets or that there are inaccuracies within the previous data. The previous data had little explanation on where cross sections were located, other than at a few places, such as bridges and the dam. In addition, there were only two cross sections per river mile in the study reach, and only half of the sections had detailed bathymetric data in the river channel. However, the cross sections did provide out-of-water topography (based on a contour map developed from September 30, 1978, aerial photographs), which was not done in the July 1999 survey.

Based on the limited data available, cross section input data for the models were developed by calibration with the water surface elevations measured in 1999. The data collected in 1999 document the channel thalweg and water surface elevation corresponding to a discharge of 3,870 ft^3/s. In the pool just upstream from the Applegate River, the depth sounder broke, but water surface elevations and visual observations were recorded. The FEMA cross sections document the out-of-water

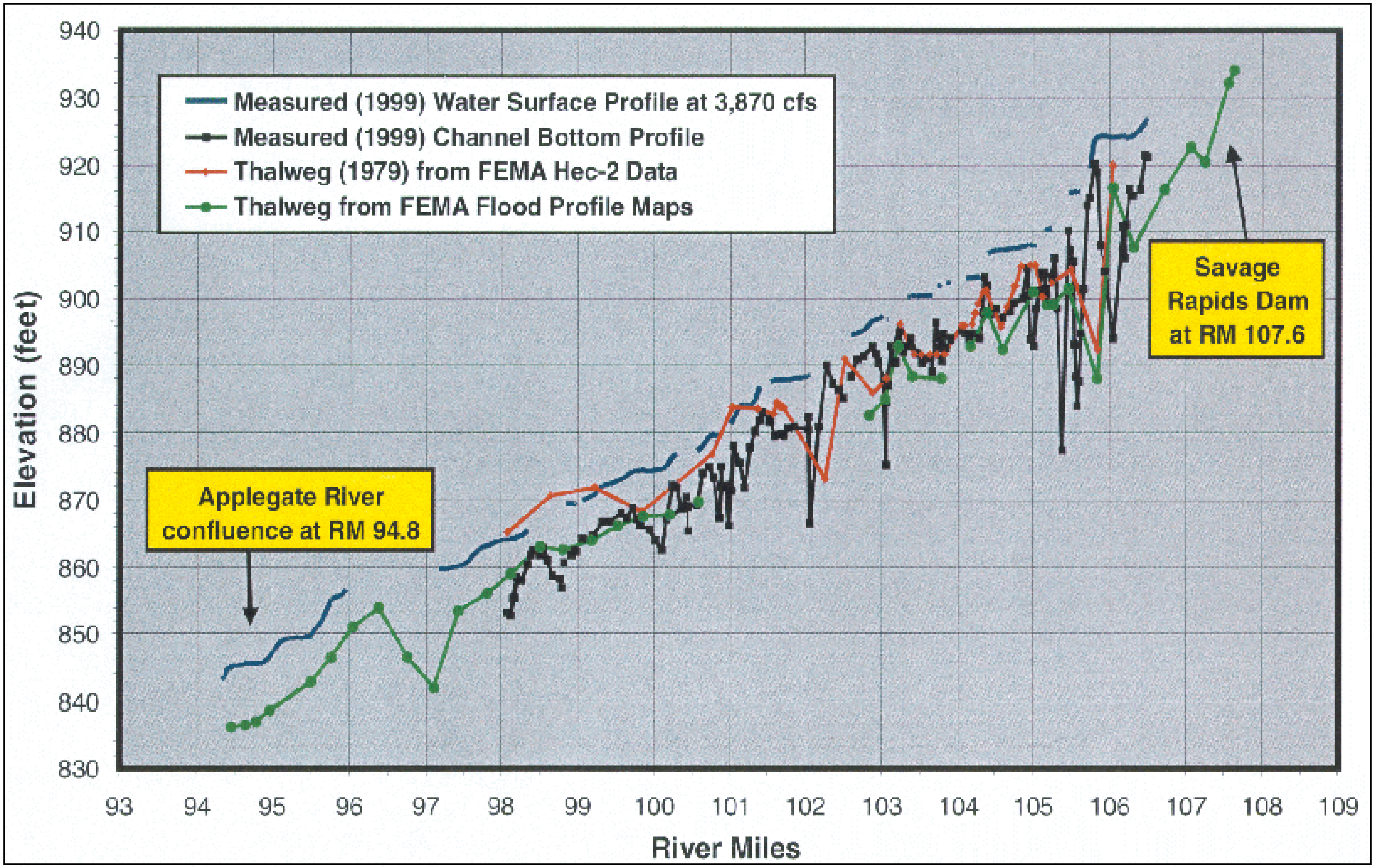

Figure 6.—Survey data collected by Reclamation downstream from Savage Rapids Dam in 1999 was compared to two sets of channel bottom data from a 1979 FEMA flood profile study. In many places, the FEMA channel bottom plots above the existing water surface, and the two sets of FEMA data are not consistent. The FEMA data were not able to be used for this sedimentation study because of the inaccuracies in the data sets, the limited documentation on the development of the data, and because only one cross section per river mile contained detailed underwater data in the river channel.

topography downstream from the dam. In this reach of river, the out-of-water topography consists of steep banks and cliffs that would not have changed since 1978, the year the photographs were taken that were used to develop this portion of the data. In addition, the width of the river channel was digitized from the U.S. Geological Survey (USGS) quadrangle maps to interpret wetted channel width at locations where depth measurements were taken in 1999. Because the banks on the Rogue River are steep, water depth increases much more rapidly than the wetted width during floods. Therefore, the wetted width interpretations from the quadrangle maps are accurate for modeling purposes. Finally, cross section shapes were evaluated based on the model calibration and cross section measurements documented at the USGS gauge site downstream from the dam (RM 102). It was noted that the pool cross section at the USGS gauging station had a triangular shape (figure 7).

Two types of cross sections were needed to represent the river channel downstream from the dam. Based on the longitudinal profile survey of 1999, the river channel consists of alternating pools and riffles (figure 3). The largest factors influencing the hydraulics of a pool section are the wetted width and water depth. Based on data collected for channel depth, wetted width at the water's surface, channel shape, and general out-of-water topography, cross sections were developed at each of the locations where a measurement was taken in 1999. Once the sections were developed, they were calibrated to adjust the only portion of the section not measured, the bottom width. A roughness coefficient of 0.035 was used in the river channel and was not changed during the calibration. Using the Corps' Hydrologic Engineering Center's River Analysis System (HEC-RAS) model version 2.2 (Brunner, 1997), the bottom width at each section was adjusted until the computed water surface elevation matched the measured water surface elevation for a discharge of 3,870 ft^3/s (discharge recorded during the 1999 survey). A table of computed river hydraulics for the calibrated cross sections and Savage Rapids Reservoir cross sections for the discharge during the survey is presented in attachment C.

To model the hydraulics through riffles and rapids, trapezoidal cross sections were developed. One cross section was always located at the top of the rapid (upstream end), representing the hydraulic control for the upstream pool, and the other at the bottom of the rapid (downstream end), representing the start of the next pool downstream. The drop in water surface elevation through the riffles and rapids was measured during the 1999 survey.

The methodology used to develop the cross sections downstream from the dam for model input did require some approximation of channel geometry. However, the channel thalweg, water depth, and wetted width were measured, so the only estimation remaining was the bottom width of each section. Because the bottom width was calibrated using a known water surface elevation, the hydraulic parameters computed through each section are accurate for the detail required in this study. Although a more detailed survey of the river channel downstream from the dam would be useful, the logistics of this type of survey would be difficult. Because the Rogue River is constrained by high cliffs and tree cover, survey capability with GPS equipment from bank

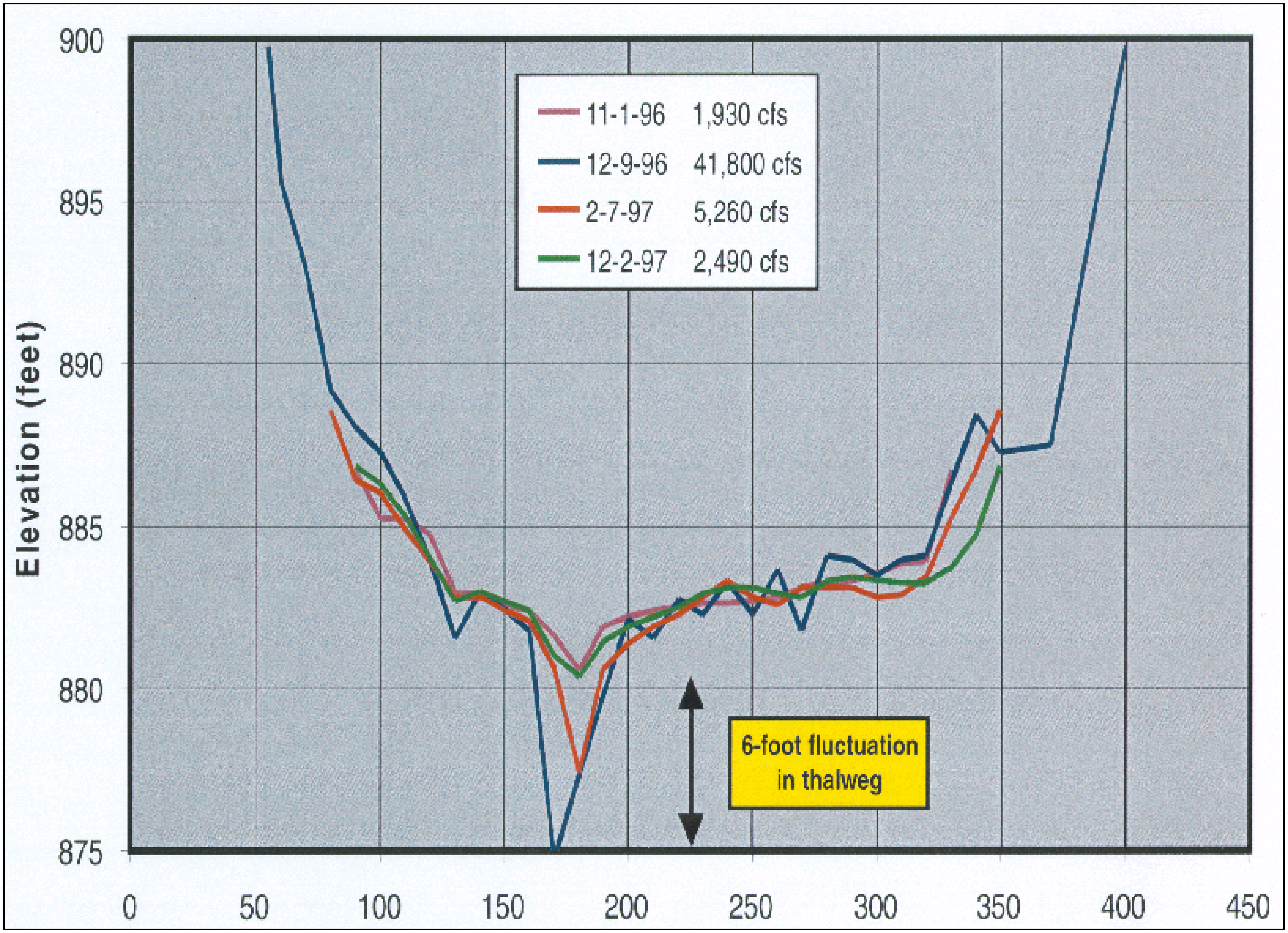

Figure 7.—Measured cross section profiles of the USGS gauging station were compared for a flood that occurred during the winter of 1996-97.

to bank would be limited. Traditional total station surveying techniques could be used but would be time consuming and, therefore, more expensive. However, it would be both beneficial and efficient to choose river pools between the dam and the Applegate River to survey in more detail. This survey data could be used to verify the calibrated cross sections and document the river channel geometry prior to releasing the reservoir sediments and for monitoring purposes.

Hydraulic and Sedimentation Model Analyses

Hydraulic Model

A Corps' river hydraulics model, HEC-RAS Version 2.2 (Brunner, 1998), was applied to the study reach. HEC-RAS is a one-dimensional, steady flow backwater model that computes hydraulic parameters for any given cross section at any discharge. The data needed to create the model were channel geometry in the reservoir, channel geometry down-stream from the dam to the confluence with the Applegate River, channel roughness (parameters that increase flow resistance), and water discharge. The model was calibrated to measured water surface elevation data to ensure its capability to accurately predict hydraulic parameters at any discharge of interest (figure 8). Model results were used to compare water surface elevation, average velocity, and water depth for existing river and reservoir conditions to conditions after the dam is removed.

For this analysis, a combination of subcritical flow in the pool cross sections and critical flow through the riffles and rapids were modeled. A downstream boundary condition (necessary for subcritical flow regime computations) of critical depth was used at the cross section farthest downstream. For pool cross sections, a roughness coefficient of 0.035 was used. During low flow periods, every pool water surface elevation is relatively flat and is a function of the water surface elevation at the top of the rapid immediately downstream from each pool, also referred to as hydraulic control. The water depth at these hydraulic control sections is at the minimum specific energy (critical depth) and can be computed directly because it is a function of only the channel geometry and discharge (not channel roughness). Therefore, the hydraulics in one pool are independent of another. During high flow periods, the slope of the water surface through many of the shallow pools (typically less than 10 feet deep) becomes steeper because at high flows, many of the smaller riffles get drowned out and no longer function as hydraulic controls (figure 9).

Dam Removal Sedimentation Model

A sediment transport model, HEC-6t (Thomas, 1996), was applied to the study reach to simulate the removal of Savage Rapids Dam. The 15-mile reach of river modeled was from the upstream end of the reservoir to the confluence with the Applegate River. The

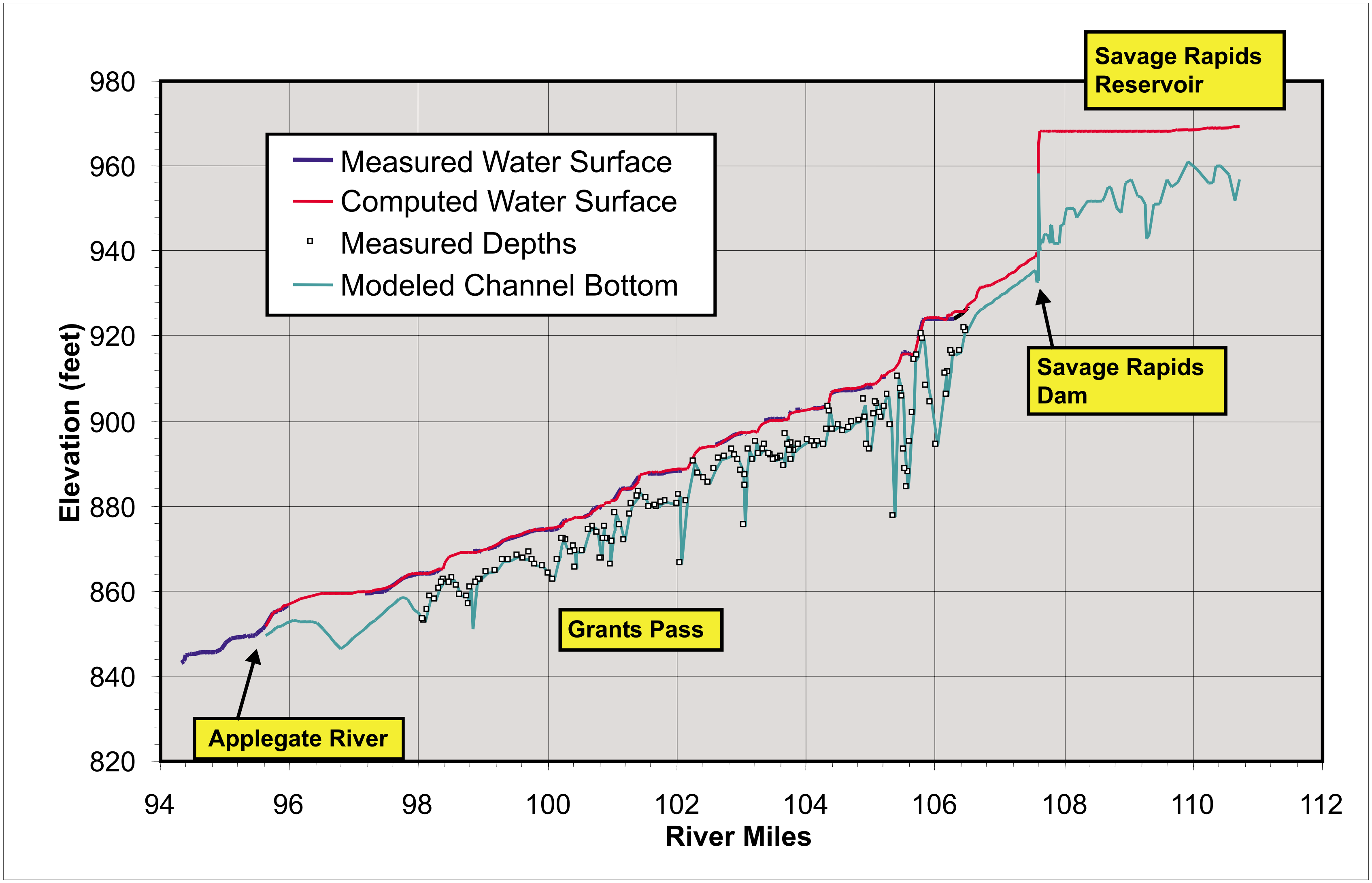

Figure 8. - The hydraulic model was calibrated to the measured water surface elevation data to ensure its capability to accurately predict hydraulic parameters at any discharge of interest. Calibration results show that the computed water surface elevation match very closely to the measured data.

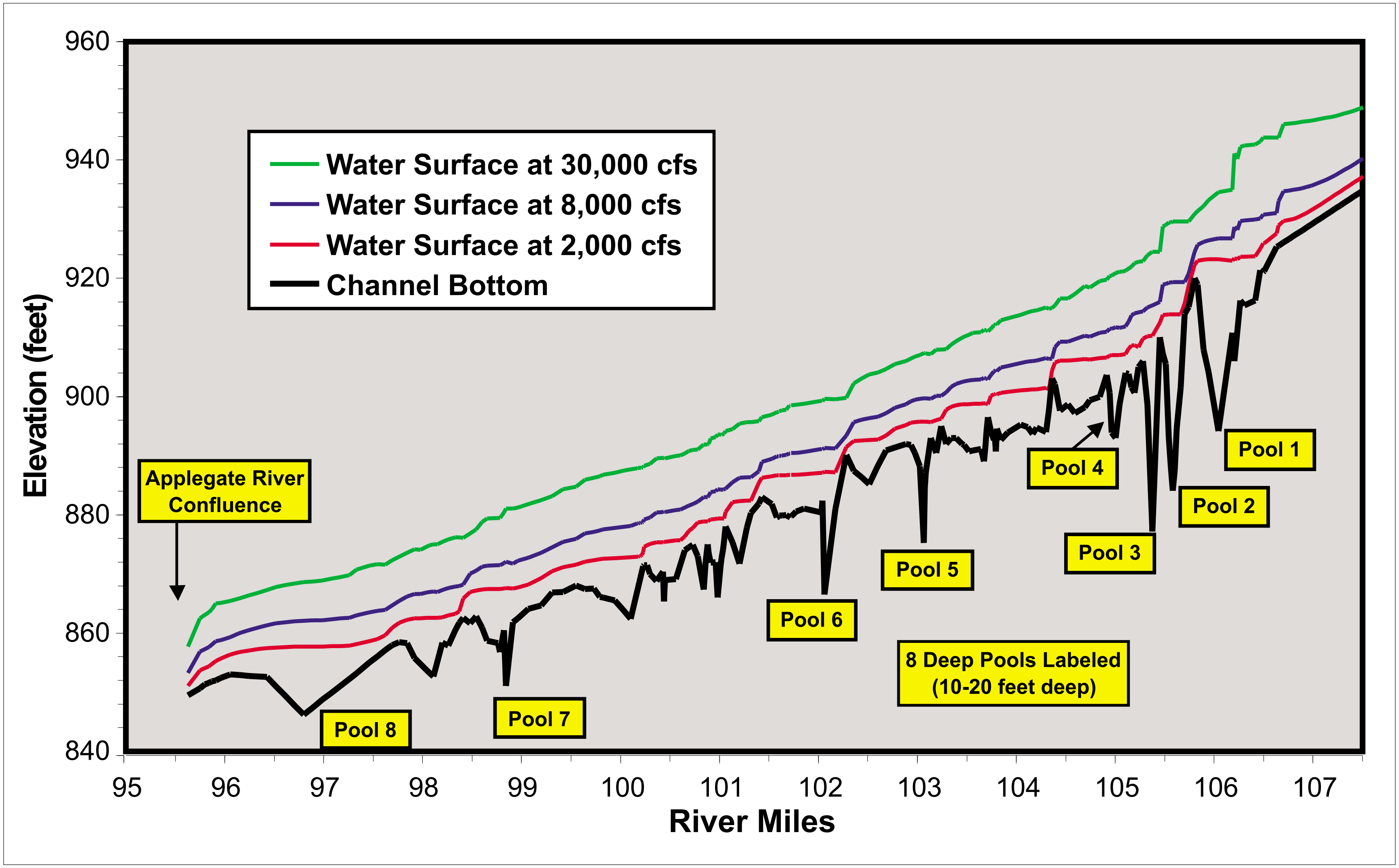

Figure 9. - During low-flow periods, pool water surface elevations are relatively flat and are controlled by the top of each riffle or rapid immediately downstream. During high-flow periods, the slope of the water surface through many of the pools becomes steeper, and smaller riffles get drowned out and no longer function as hydraulic controls.

additional data needed for the sediment model were the size and thickness of sediment present on the reservoir and river bottom, the natural upstream sediment supply of the Rogue River at the dam, and a hydrograph depicting riverflows over a period of time. Model input files are stored at Reclamation's Denver Office.

Model results were used to analyze the rate of erosion, the volume of sediments eroded from the reservoir, and the rate of transport of these sediments downstream. At this time, a specific dam removal study that details the timing and sequence of dam removal has not been initiated. Alternatives for removing the dam range from removing it very quickly, over a period of months, to removing it gradually, over a period of years. For this study, it was assumed the dam had just been removed, and all the reservoir sediments could immediately begin eroding downstream.

The use of steady-flow models is considered appropriate for this study because the dam would be removed in a controlled way that would not generate a flood wave. Also, the shape (duration and peak) of natural flood waves that would typically occur on the Rogue River probably would not change much as they flowed through the 12-mile study reach. For the hydraulic model, the assumption of steady flow is entirely adequate for the calibration of the cross-section geometries. For the sediment transport model, a series of short-duration, steady flows were used to simulate naturally occurring flood waves.

Filling of Savage Rapids Reservoir

The purpose of diversion dams is to divert water, so these dams are typically small compared to dams used for flood control or water storage. Therefore, the pool behind a diversion dam tends to fill with sediment in the first few years of operation. After filling, virtually all sediment transported by the river into the reservoir passes the dam. Therefore, Savage Rapids Dam, built in 1921, would be expected to have filled with sediment long ago.

On the Rogue River, nearly all the sediment is naturally transported during periods of high flow. High flow typically occurs during winter floods and the spring snowmelt runoff. Because the reservoir pool is lowered and extends only a ½ mile upstream during these high-flow periods, river conditions exist upstream from the public ramp (figure 10). These river conditions cause high velocities, and high velocities mean the dam does not cause sediment deposition in the upper 2 miles of the reservoir (from the public boat ramp to Evans Creek). Observations made by divers, who traversed the channel bottom, and visual observations made above water while the reservoir pool was lowered for stoplog installation, confirmed that no sediment is being stored in the upper 2 miles of the reservoir.

Also, before the dam was built, a riffle existed at the dam site and a river pool, which is now buried with sediment, existed just upstream at RM 107.91 (figure 11). If the dam

Figure 10. - After the stoplogs are removed following the irrigation season, riverine conditions exist upstream from the public boat ramp in Savage Rapids Reservoir.

Figure 11. - This photograph shows the pre-dam river channel at the current location of Savage Rapids Dam. Prior to the construction of the dam, a riffle existed at the dam site, which created a pool immediately upstream.

caused sediment deposition in the upper 2 miles of the reservoir, any other pools that existed would have quickly filled in with sediment and would also now be buried. However, the survey of the reservoir bottom found several pools that exist upstream from the public boat ramp. This further supports the concept that sediment does not deposit upstream from the public boat ramp. Therefore, the sediment deposition caused by Savage Rapids Dam occurs in the ½-mile reach just upstream from the dam.

Coarse sediment (sand and gravel), which travels as bedload, has deposited in this ½-mile reach (figure 12). Fine sediment (silt and clay) is easily suspended in the water column and carried past the dam. This permanent sediment deposition probably occurred within the first few years after the dam was built. Since that time, all the sediment entering the reservoir, mostly during high flows, passes the dam. Visual observations during a reservoir drawdown confirm that even gravel-sized sediment is being transported past the dam (figure 13).

Inflowing Sediment Load

In addition to predicting the transport and deposition of reservoir sediment following a dam removal, the sediment model must also account for the transport of the natural upstream sediment supply of the river. Because most of the sediment supply carried by the Rogue River consists of sand and gravel, most sediment is transported as bedload. Unfortunately, there are no bedload measurements downstream from Savage Rapids Dam. To estimate what the natural sediment load is, the HEC-6t model was used to determine the sediment transport capacity.

While the typical process of scour and fill occurs along the channel bed during and following high flow periods, the Rogue River (upstream from the Applegate River) does not have excessive amounts of sediment stored along the channel margins. This is not a result of sediment being trapped behind Savage Rapids Dam, because the year-round reservoir filled long ago and has been passing the river's sediment through for several decades. In addition, Lost Creek Reservoir (located 50 miles upstream from Savage Rapids Dam) traps sediment from 30 percent of the Rogue River watershed that is upstream from Grants Pass, Oregon. A few other reservoirs, such as Emigrant Lake, may also trap a small amount of sediment that would otherwise be delivered to the Rogue River. However, these drainage areas are small relative to that of the Rogue River, and they were not within the scope of this study. This implies that the transport capacity of the river is larger than the amount of sediment currently supplied at Grants Pass. Therefore, it would be reasonable to assume that the present-day sediment load is equal to 70 percent of the total sediment transport capacity. The transport capacity was computed for a variety of flows to develop a relationship between discharge and present-day sediment load for input to the HEC-6t model (figure 14).

Based on the computed sediment-discharge rating curve for incoming sediment load, the average annual sediment load of the Rogue River was computed and used as the input boundary conditions for the sediment model. Mean daily flows since 1977 (when Lost Creek Dam was completed) were used to compute the present-day average annual

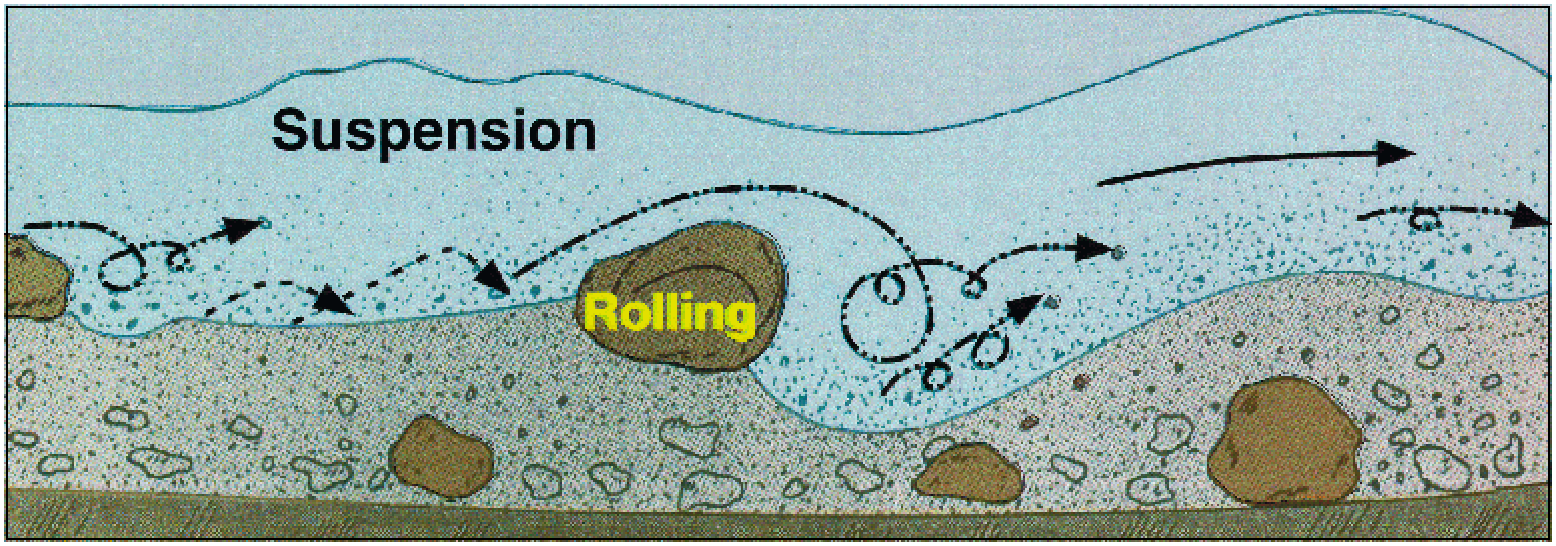

Figure 12.—Coarse sediment (sand and gravel) are transported as bedload along the river channel bottom. Fine sediment (silt and clay) are transported in suspension.

Figure 13. - Upstream face of Savage Rapids Dam - During a reservoir drawdown in May 1999, gravel-sized sediment was observed on the crest of the dam, indicating that sediment is transported past the dam during spillway releases.

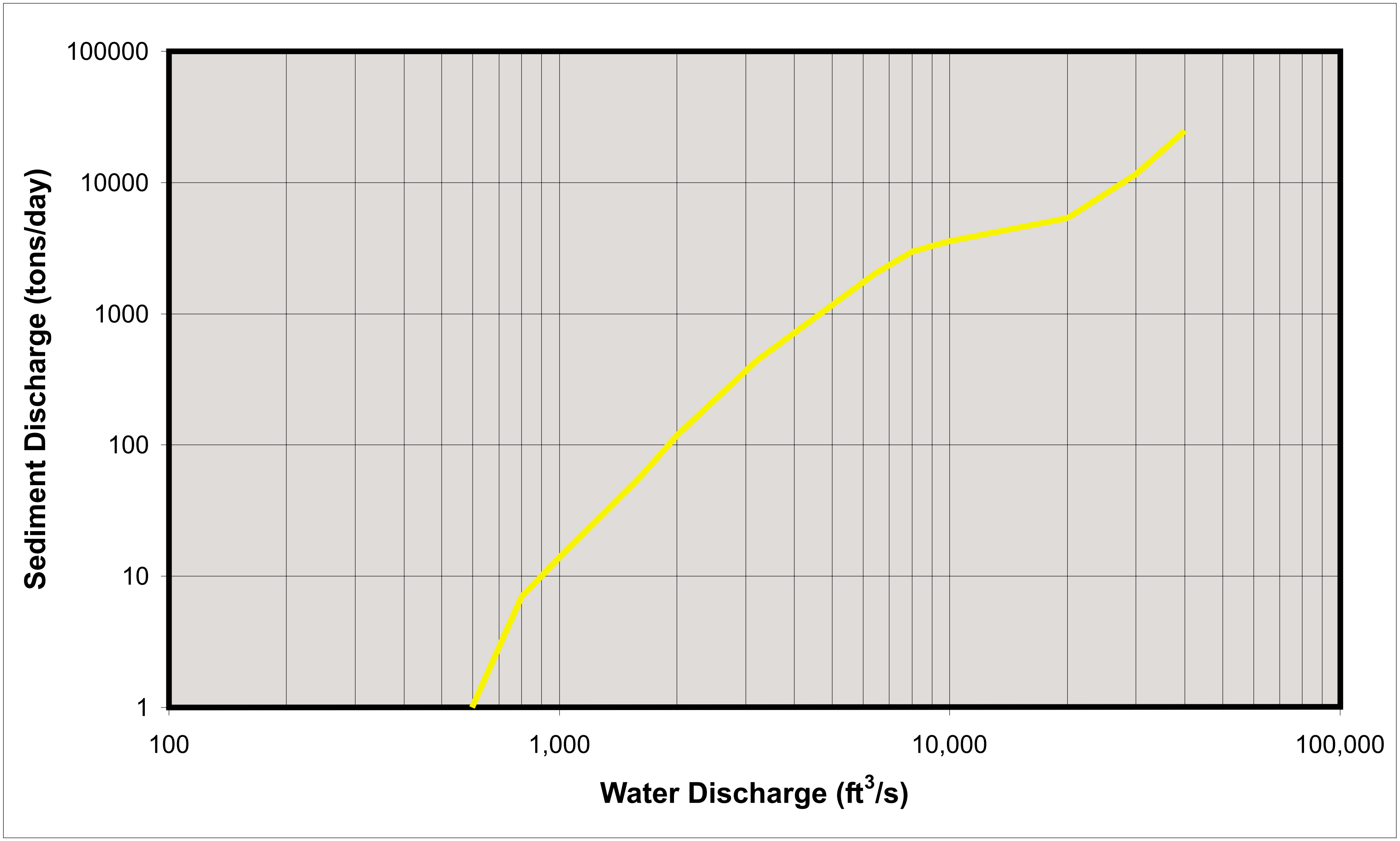

Figure 14. - the sediment transport capacity was computed using the HEC-6t sediment model for a variety of flows to develop a relationship between discharge and incoming sediment load of the Rogue River near Grants Pass, Oregon.

sediment load, approximately 100,000 cubic yards (yds^3). The sediment load accounts for 70 percent of the transport capacity. While there is no true average year on a river, the 200,000 yds^3 of reservoir sediments trapped behind the dam is roughly equivalent to two average years of sediment load carried by the Rogue River at Grants Pass. This volume quickly diminishes in scale as the river travels downstream past the confluences with the Applegate and Illinois Rivers, both large contributors of sediment to the Rogue River.

To ensure that the calculation of average annual sediment load was not overestimated or underestimated as a result of using mean daily flows rather than hourly flows (higher peak values), a comparison was made using hourly data from a winter 1996-97 storm (figure 15). Because two separate flow peaks occurred, the mean daily load actually overestimated the load computed with hourly values by 3 percent. In general, the mean-daily load would approximate sediment load values very well for the Rogue River, based on this comparison.

Modeled Hydrograph of Riverflows Following Dam Removal

The riverflows following dam removal are an unknown, but the historic flows on the Rogue River can be used as an indicator of what can be expected to happen in the future. Riverflows have been recorded since 1939 at a USGS gauging station near Grants Pass, Oregon (figure 16). Flood peaks on the Rogue River typically occur from November to March, with most occurring in December and January. The largest mean daily flow recorded on the Rogue prior to construction of Lost Creek Reservoir was 124,000 ft^3/s (instantaneous peak of 152,000 ft^3/s) in December 1964. Local records and photographs document that large portions of Rogue River, Oregon, were inundated, and numerous homes were destroyed. Following the construction of Lost Creek Dam, the frequency of flood peaks has declined significantly, as seen in the winter flood of 1996-97 (figure 17). The largest flood since Lost Creek Dam was constructed occurred during January 1997, when the mean daily flow reached 69,000 ft^3/s (instantaneous peak of 90,800 ft^3/s).

The Rogue River naturally transports sediments during high flows, when velocities and water depths increase, thus increasing the capacity of the river to transport material. Larger particles, such as sand and gravel, which are common particle sizes in the Rogue River, are transported along the channel bed and are therefore called "bed material." Smaller particles, such as silt and clay, are transported in suspension and are called "suspended material." The amount of sediment transported depends on both the size of the sediment and the unit stream power (velocity times slope) of the river. As flows recede and transport capacity is reduced, sediment is temporarily deposited along the channel bed in slow velocity zones, such as pools or eddies (areas of recirculating flow). This cycle is a natural process along the Rogue River. During wet years consisting of numerous high flows, more sediment is transported and reworked downstream than during dry years when very few high flows occur.

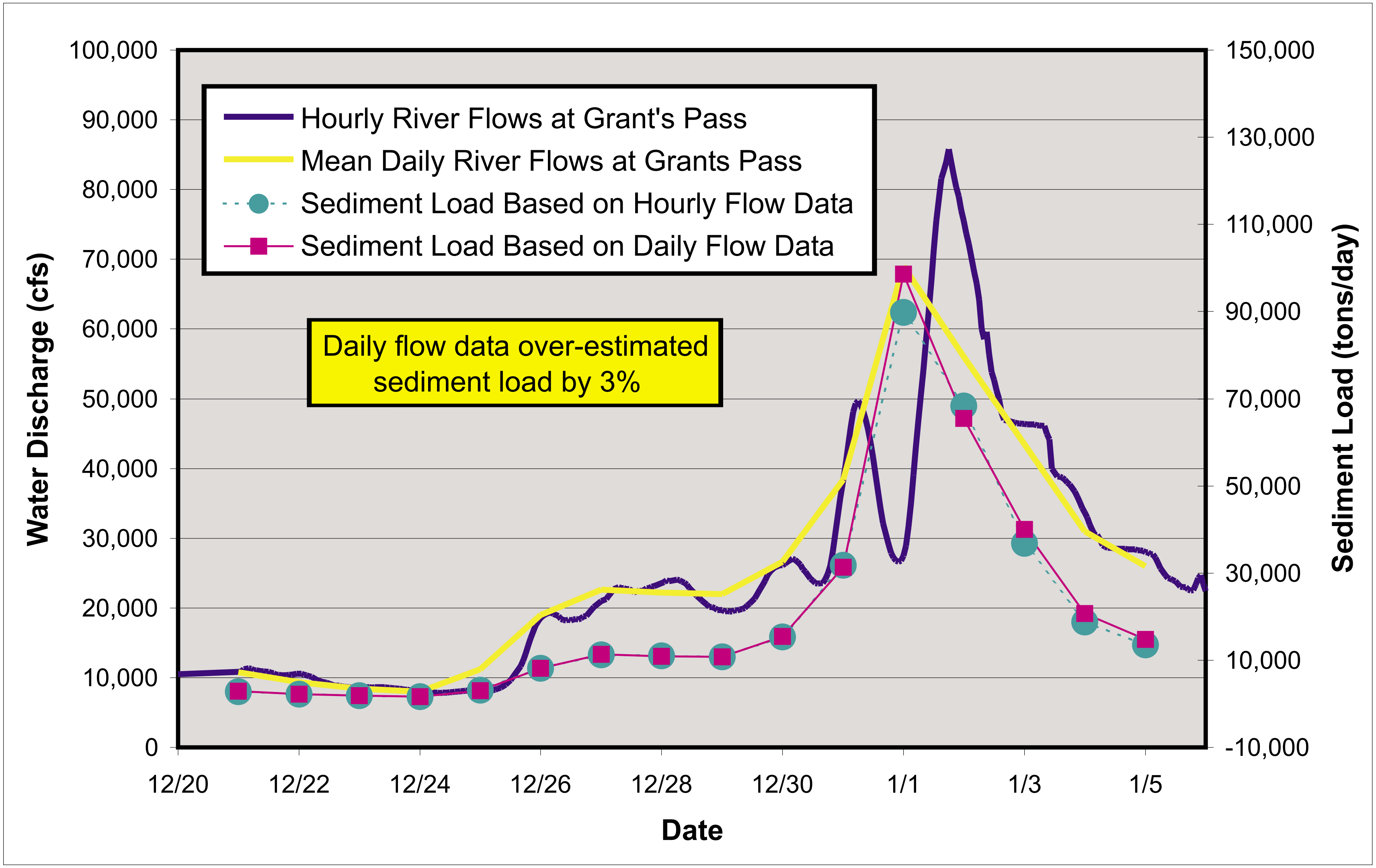

Figure 15. - A comparison between predicted sediment load using mean daily flows versus hourly flow data was done for the largest flood that has occurred on the Rogue River at Savage Rapids Dam since Lost Creek Dam was constructed in 1977. The results showed that both sediment load computation methods produced similar results. In this particular flood, there were 2 peaks, which causes the sediment load computations using the mean daily flow values to be greater since the mean daily flows (shown in yellow) essentially lump the two flood peaks (shown in dark blue) into one flood.

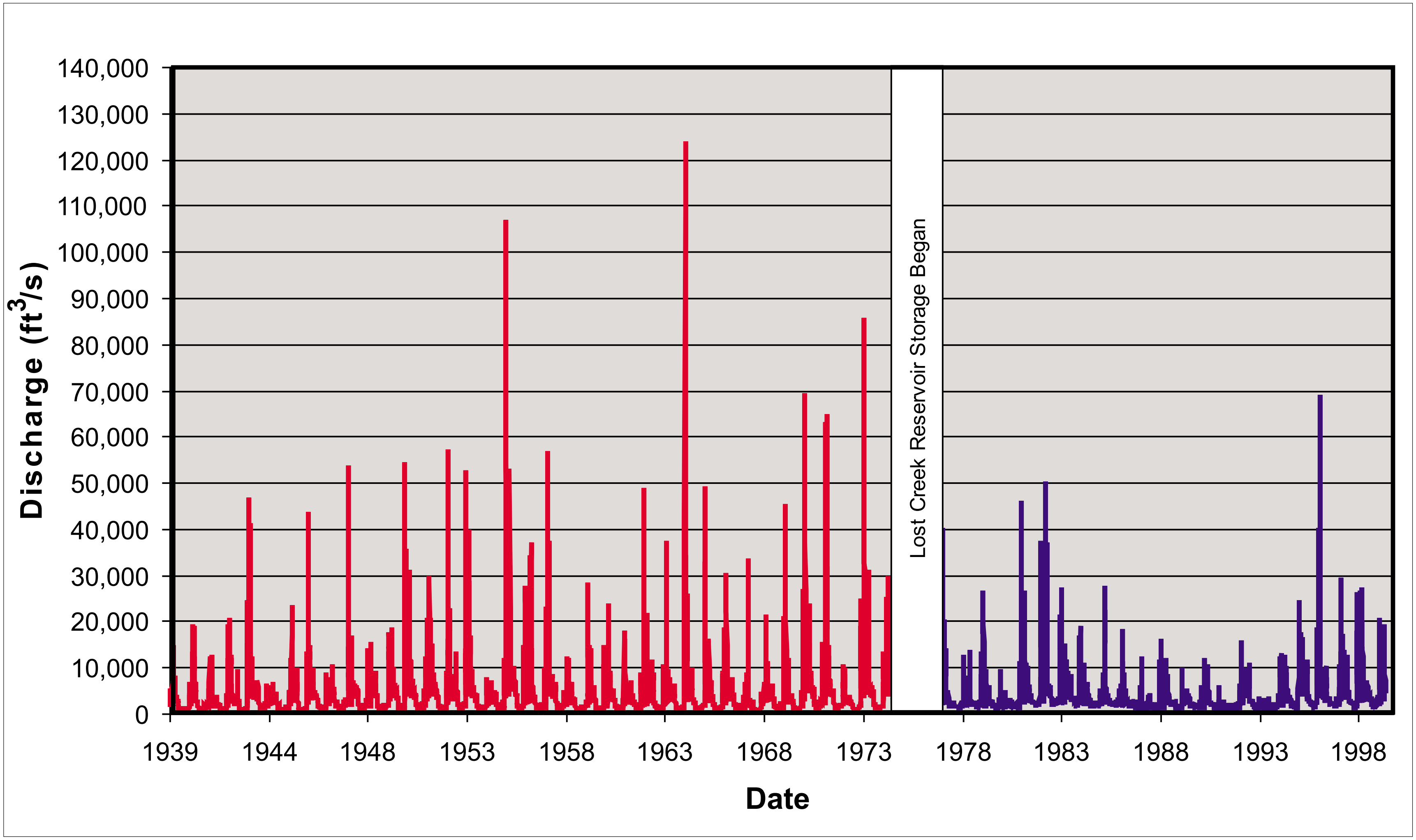

Figure 16. - Riverflows have been recorded on the Rogue river at the USGS gauging station at Grants Pass, Oregon, since 1939. In February 1977, storage in Lost Creek Reservoir (a flood control reservoir located 50 miles upstream from Savage Rapids Dam) began resulting in a reduction of flood peaks at Grants Pass. Since Lost Creek Dam was built, the largest flood occurred during the winter of 1996-97. Several years during the late 1980s and early 1990s had very few peak flows during the winter flood season.

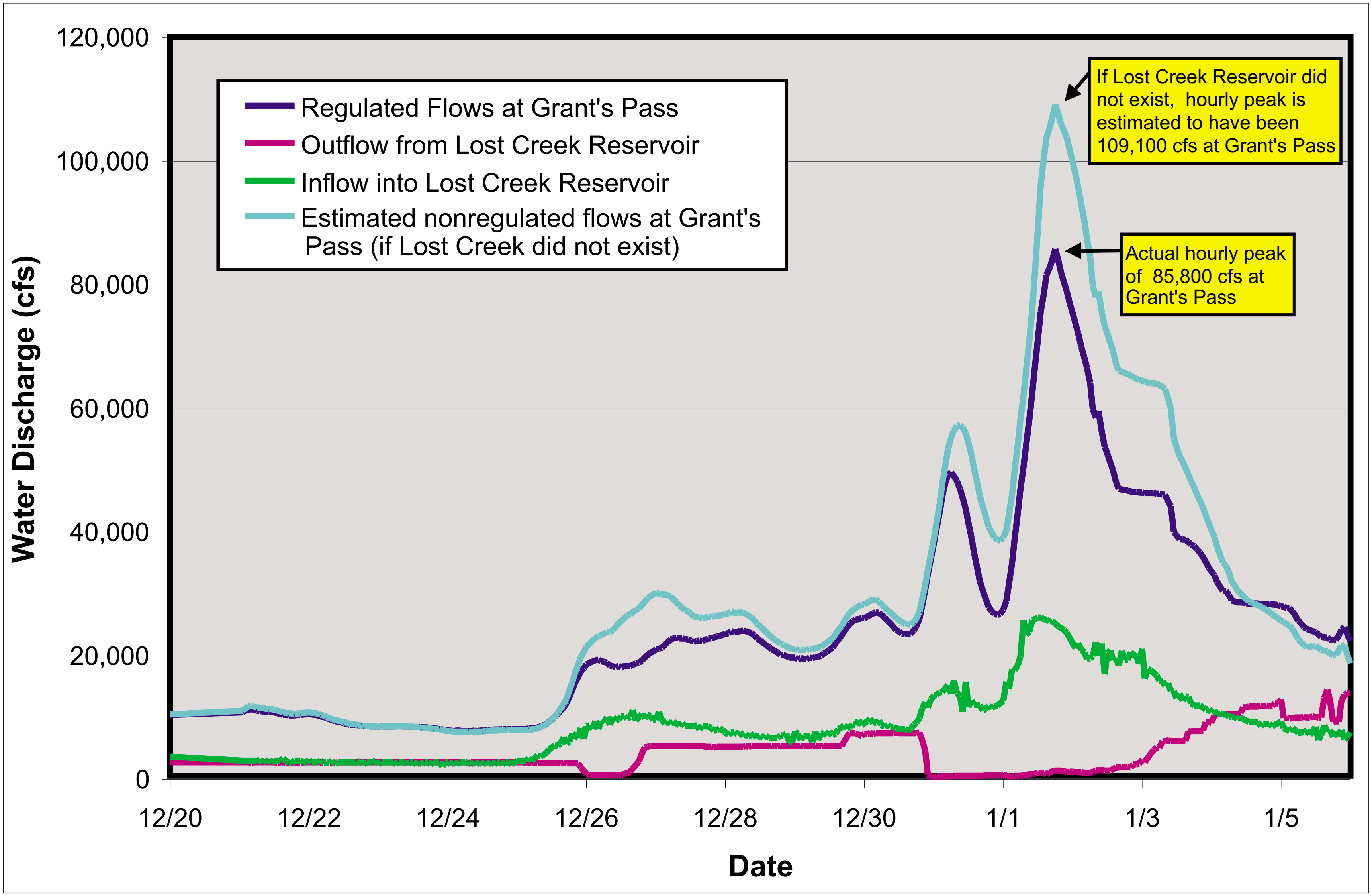

Figure 17. - Following the construction of Lost Creek Dam, the frequency of flood peaks at Grants Pass have been significantly reduced. However, during large peak flows, such as the one depicted in the winter 1996-97 hydrograph above, flows at Grants Pass are still large in magnitude even with the regulation at Lost Creek Reservoir.

Riverflows following dam removal will determine how fast the reservoir sediment is transported downstream. The more frequent the peak flows and the greater their magnitude, the quicker sediments will be transported to the ocean. Looking at the historic data since Lost Creek Dam was constructed (see figure 16), a period of dry years (where very few winter storms occurred) started in the late 1980s. Before and after this period, several wet years were recorded when numerous winter storms occurred. Two possible extremes were modeled: (1) dam removal followed by several dry years, as occurred in the late 1980s, and (2) dam removal followed by the wettest year that was recorded (winter of 1996-97), followed by subsequent wet years. Both scenarios used the period of record data (in chronological order) since 1977 because these are realistic flow values that actually occurred on the Rogue River.

The first scenario represents the extreme of starting the dam removal and reservoir sediment erosion at the beginning of the dry years on the Rogue River, as seen in the historical data. The hydrograph starts at the first year of the dry cycle in 1987 and ends with the wet year cycle (figure 18). When the end of the period of record was reached in year 2000, the hydrograph data were wrapped to include the 1977 to 1987 data. The second scenario represents the other extreme of starting the dam removal in a year with the highest recorded mean-daily flow, 69,000 ft^3/s (winter 1996), followed by several wet years (1997-2000) and ending with the drought that started in the late 1980s (figure 19). Both hydrologic extremes modeled a possible dam removal in May (the summer low flows and the irrigation season start in May) and in November (after the irrigation season but at the start of the winter flood season).

Model Priming

The manual for HEC-6 states that if the calculated sediment model results do not follow the observed trends, the user must "prime" the model (Corps, 1993). There are eight downstream river pools between Savage Rapids Dam and the Applegate River that are prone to significant sediment deposition because of their relatively low sediment transport capacity. The initial sediment model results showed that these eight river pools would fill to capacity as a result of the release of reservoir sediments following a dam removal (attachment D). However, measured data indicate that the annual sediment load currently getting past the dam during high flows has not caused these pools to fill up. If this model result were true, these pools would have filled long ago from the natural sediment load of the river. Priming the model allows the user to stabilize the model for natural conditions (estimated incoming sediment load), and then model only the net change from a significant event, such as the removal of a dam.

Although the initial results could not be used to model the dam removal until model priming is done, the results can be used to approximate the maximum sediment storage capacity of these eight pools (table 1). This capacity of 280,300 yds^3 accounts for 61 per-cent of the total storage capacity downstream from the dam and is nearly 1.5 times the reservoir sediment volume. The remaining 39 percent of sediment storage capacity is in the 10 shallow pools and several eddies that exist throughout the reach.

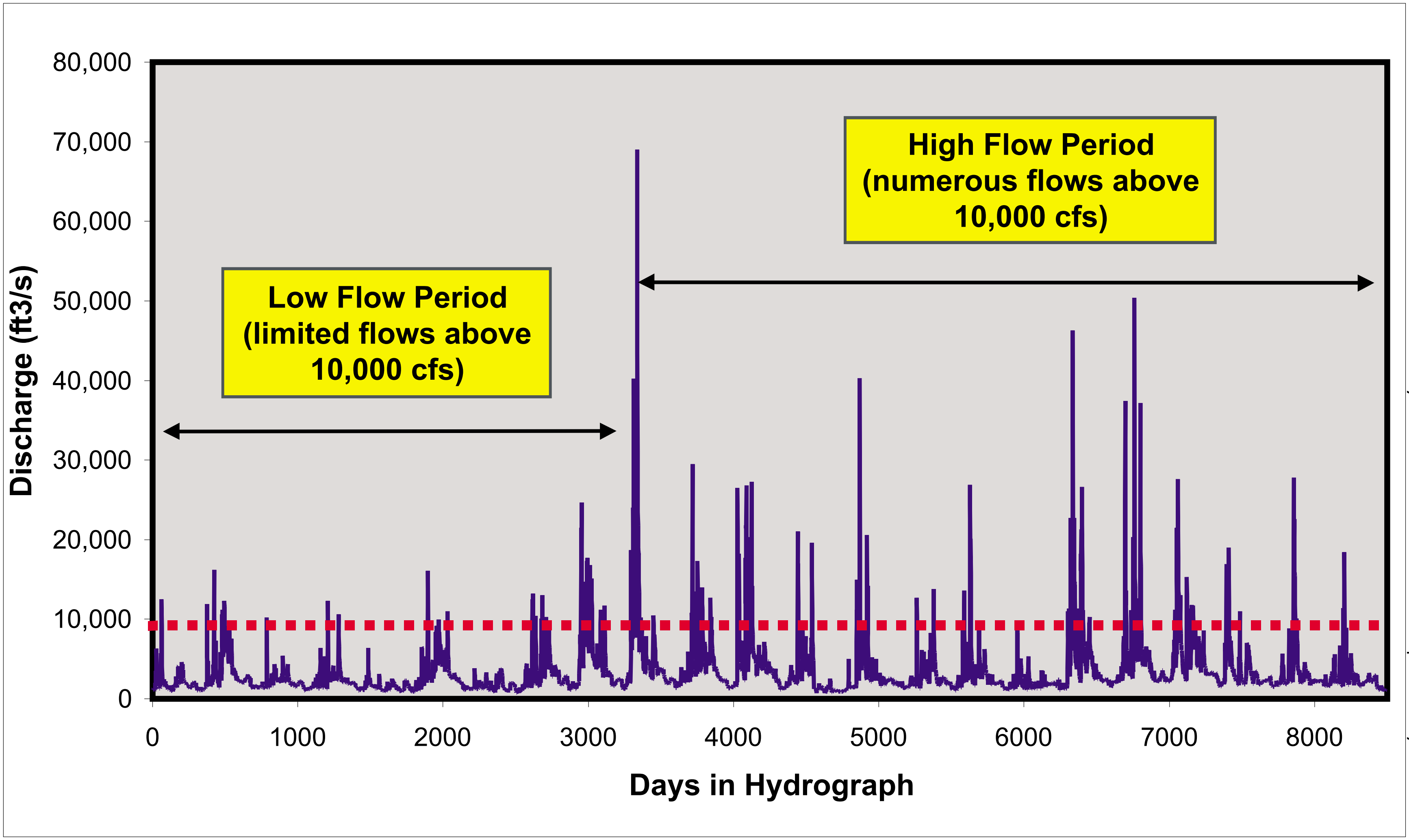

Figure 18. - Hydrograph A represents one possible scenario of riveflows following dam removal. This hydrograph begins with a dam removal followed by a dry period where very few peak flows occur during the winter flood season. This hydrograph was created using actual USGS data at the gauging station at Grants Pass since 1977 when Lost Creek was established.

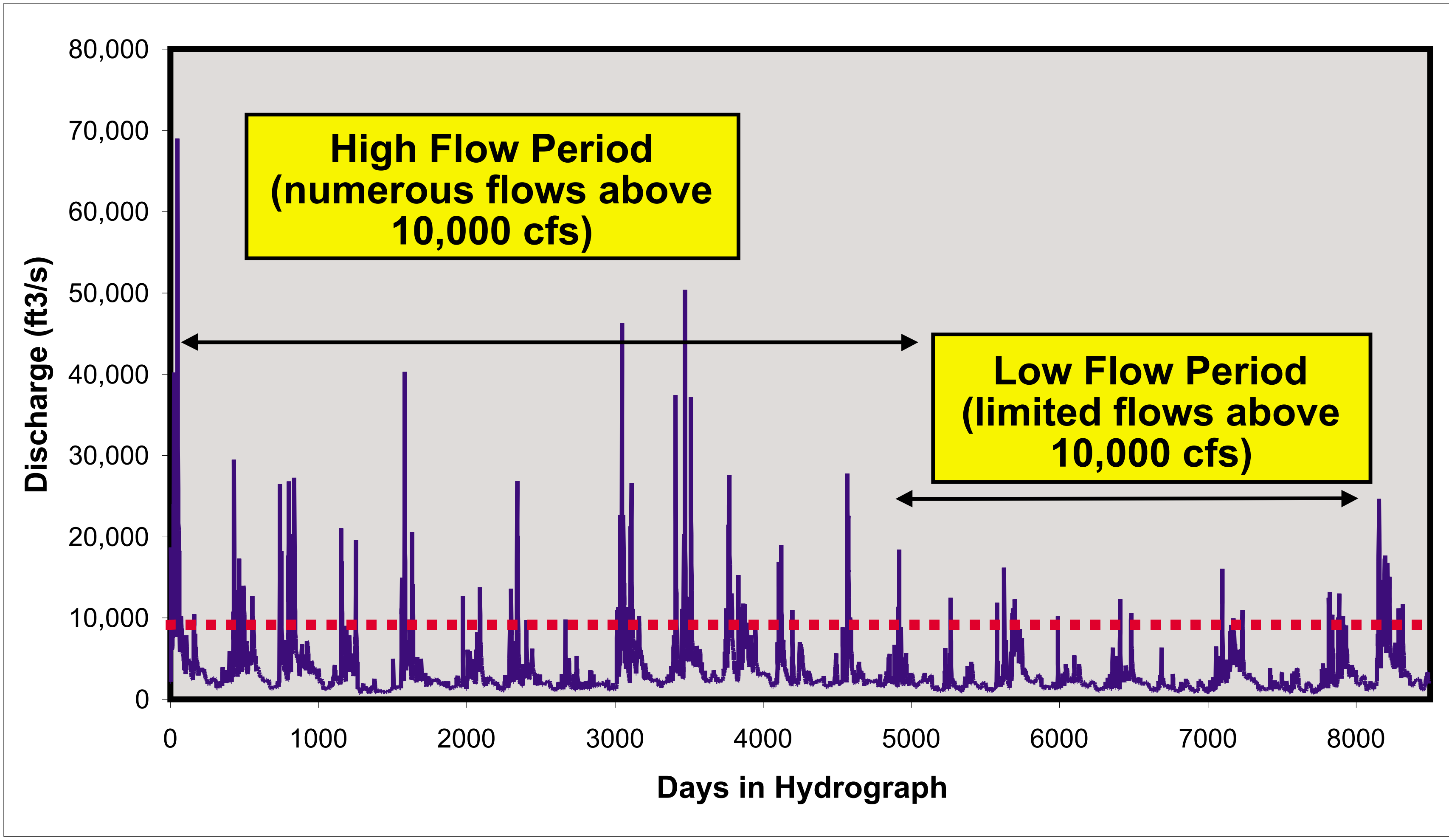

Figure 19. - Hydrograph B represents one possible scenario of riverflows following dam removal. This hydrograph begins with a dam removal followed by a wet period where several peak flows occur during the winter flood season. This hydrograph was created using actual USGS data at the gauging station at Grants Pass since 1977 when Lost Creek was established.

Table 1. — Maximum sediment storage capacity of deep river pools downstream from Savage Rapids Dam

	River mile location (middle of pool)	Maximum sediment storage capacity (yds³)	Cumulative sediment storage capacity (yds³)	Cumulative % of total storage downstream (Dam to Applegate River)
Savage Rapids Dam	107.60	—	—	
Pool 1	106.04	69,600	69,600	15
Pool 2	105.58	32,600	102,200	22
Pool 3	105.37	35,600	137,800	30
Pool 4	105.00	300	138,100	30
Pool 5	103.06	14,900	153,000	33
Pool 6	102.06	28,000	181,000	39
Pool 7	98.78	25,300	206,300	45
Pool 8	96.79	74,000	280,300	61
Applegate River	95.00	—	—	

To prime the model, a flow hydrograph was created that consisted of approximately 1-½ years of a constant flow of 8,000 ft^3/s, followed by the period of flow record in chronological order from 1977 to the present (24-½ years). A constant flow of 8,000 ft^3/s was chosen to start the priming run because it allows the model to initially stabilize at a flow that is large relative to typical low flows but smaller than typical peak flows on the Rogue River. After modeling a series of several floods, deposition from the natural Rogue River sediment load occurred mainly in the eight river pools with depths greater than 10 feet (attachment E). The final geometry from the model priming run was used as the input geometry for modeling the various dam removal scenarios.

Study Results and Discussion

Erosion of Reservoir Sediments

Savage Rapids Reservoir is only 2 to 3 times wider than the surrounding river channel. This means most of the reservoir sediment trapped behind the dam would be eroded by the river rather than stranded as the water surface elevation of the river quickly decreases following dam removal. Small sediment deposits may permanently remain along the margins of the reservoir.

An initial flushing of reservoir sediment would occur immediately following removal of the dam. This flushing occurs because, as the dam is removed, the river would begin incising through the sediment deposits behind the dam. This incision process and sediment flushing would continue until a stable slope is reached upstream from the dam site. This flushing would cause sediment concentrations[1] downstream from the dam to significantly increase for a short duration immediately following dam removal (figure 20). After the initial flushing, successively higher flows would be required to again increase the sediment load to the downstream river channel. As the reservoir sediments were transported past the Applegate, the concentration levels as a result of removing the dam would gradually diminish over time. Sediment concentrations will be much higher than natural conditions during the first flood following dam removal. These high concentrations will tend to decrease toward natural levels with each subsequent flood. Between floods, sediment concentrations will be relatively low.

Model results show that if Savage Rapid Dam is removed, virtually all the sediment would be eroded from the reservoir (figure 21). Regardless of when the dam is removed and what magnitudes of flows occur, about three-fourths of the reservoir sediment will be eroded within the first year after dam removal.

Transport of Reservoir Sediments Downstream from Dam

The volume of reservoir sediment stored behind Savage Rapids Dam is about 200,000 yds^3, and the sediment storage capacity of the reservoir is essentially full (Appendix A). Therefore, most of sediment that enters the reservoir from upstream is transported through the reservoir, and net sediment volume in the reservoir never significantly changes. The river pools downstream from the dam temporarily store a portion of the sediment during low flow periods, but this sediment tends to be flushed (scouring the pools) by high river velocities during floods. This natural process was observed at the USGS gauge cross section near Grants Pass (see figure 7). During a winter storm in 1996–97, the channel bed at this section scoured out 6 feet and subsequently filled back in during low-flow periods in the following year. The channel bed in this river pool was scoured 6 feet during the first peak flood in December, 41,200 ft^3/s (a second peak flood, in January, reached 69,000 ft^3/s). During the following year, this pool slowly filled back in with sediment to its pre-flood conditions.

The sediment that is eroded and flushed from the reservoir (following a dam removal) would be transported downstream. This sediment would temporarily deposit in pools and eddies (zones of recirculating flow). As sediment deposits along the bottom of pools and eddies (decreasing water depths), river velocities would increase until the velocities become so high that sediment would be transported through the reach rather than deposited. Sediment deposition in pools and eddies would most likely occur during low-flow periods. Subsequently, the sediment would be scoured out and transported downstream during high-flow periods. Eventually, all the sediment would be eroded and reach the ocean.

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[1] Sediment concentration refers to the mass of sediment transported by the river per unit volume of water. Sand-sized sediment is transported in suspension through riffles, rapids, and short pools where velocities and turbulence are high. Coarse-sized sediment (gravel and cobble) is transported as bed load.

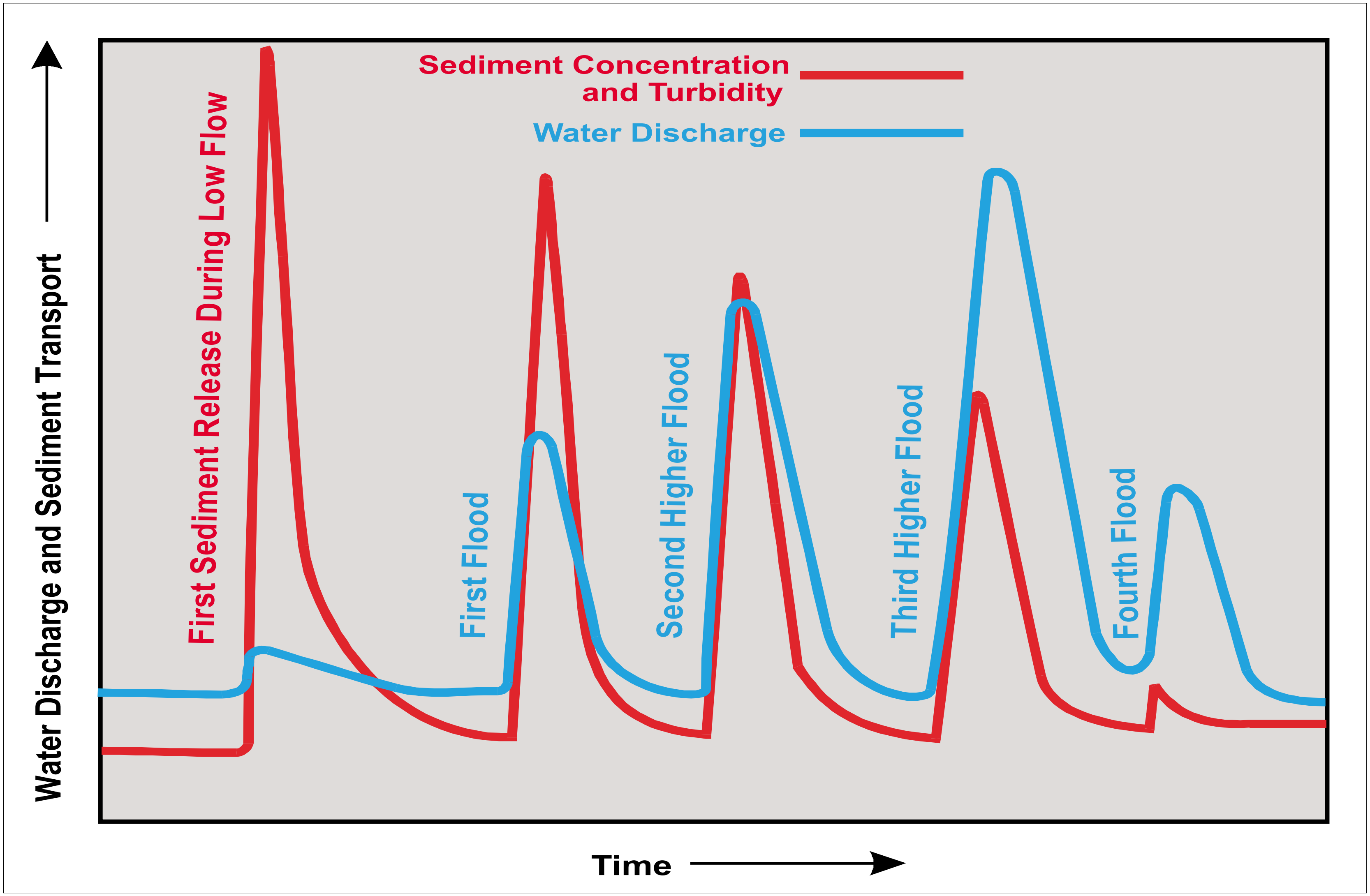

Figure 20. - Conceptual depiction of the relationship of water discharge and sediment transport in the downstream river channel folloing removal of a dam.

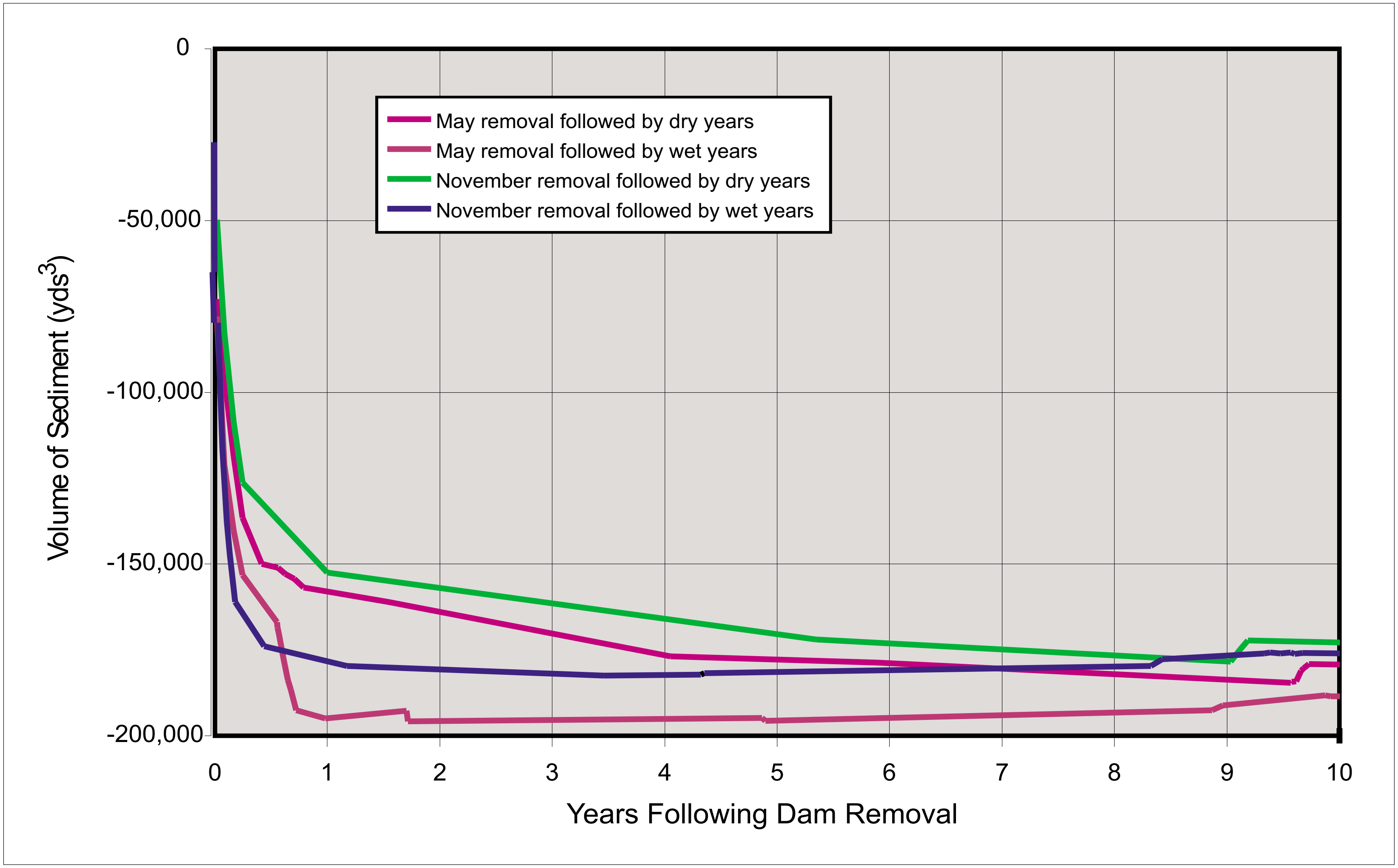

Figure 21. - This plot shows the volume and rate of sediment eroded from the reservoir following each of the four dam removal scenarios. Regardless of the hydrology in the first few months following dam removal, at least three-fourths of th reservoir sediment will be eroded in the first year. The time period before the remaining reservoir sediment would be eroded depends on the frequency and magnitude of peak flows following dam removal.

The reservoir sediment would be transported downstream from the Applegate River within a 1- to 10-year period, depending on the frequency and magnitude of high-flow periods following dam removal (figure 22). The 1-year timeframe represents the dam removal followed by an extremely wet year with several high flows, and 10 years would be a dam removal followed by several dry years with very few or no high flows. Most sediment transport would occur during floods. If flood magnitudes following dam removal are high and floods occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or floods occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels between floods.

As the sediment wave moves downstream, maximum deposition levels will occur at various times following dam removal, but not all at once. To show exactly how the sediment wave moves through the river system, a series of model results at selected time periods following dam removal was generated. The results for the dam removal in May followed by several dry years (very few high flows) is presented as individual hard copy plots (attachment F).

Attachment F includes longitudinal plots of the first 5 miles downstream from the dam showing channel bottom elevation, water surface elevation for reference, and the sediment deposition at each particular time period. The results indicate that deposition levels will range from 1 to 8 feet in river pools. Even during maximum deposition, pools that exist today will continue to exist following dam removal. Therefore, no flooding as a result of the dam removal is predicted to occur because all of the deposi-tions will occur in river pools, which will not cause any increases in water surface elevation. Areas downstream from the dam that are currently high-velocity areas, such as riffles or very shallow pools, would be subject to only minor deposition. Reservoir sediment would be transported fairly quickly through these areas during high-flow periods.

As indicated by the Rogue River stream power figure (figure 4), once the sediment passes the confluence with the Applegate River, it would be transported all the way to the Pacific Ocean. A study completed by the Corps documents that most of sediment found at Gold Beach, near the mouth of the Rogue, is sand and gravel-sized sediment, indicating that the sediment behind Savage Rapids Dam would be easily transported to the ocean (Corps, 1997). As the sediment travels through Hellgate Canyon, some temporary deposition could occur, but because of the steep slope of the canyon and narrow widths, sediment transport capacity would be very high, and sediment would probably travel through quickly (see figure 3). The amount of time for the sediments to reach the ocean depends on the frequency and magnitude of high-flow events. If several high flows were to occur immediately following dam removal, reservoir sediments would reach the ocean within a few years. However, if a long period of low flows occurs following dam removal, it could take decades for all the reservoir sediment to reach the ocean. As the sediment reaches the Pacific Ocean, the reservoir sediment

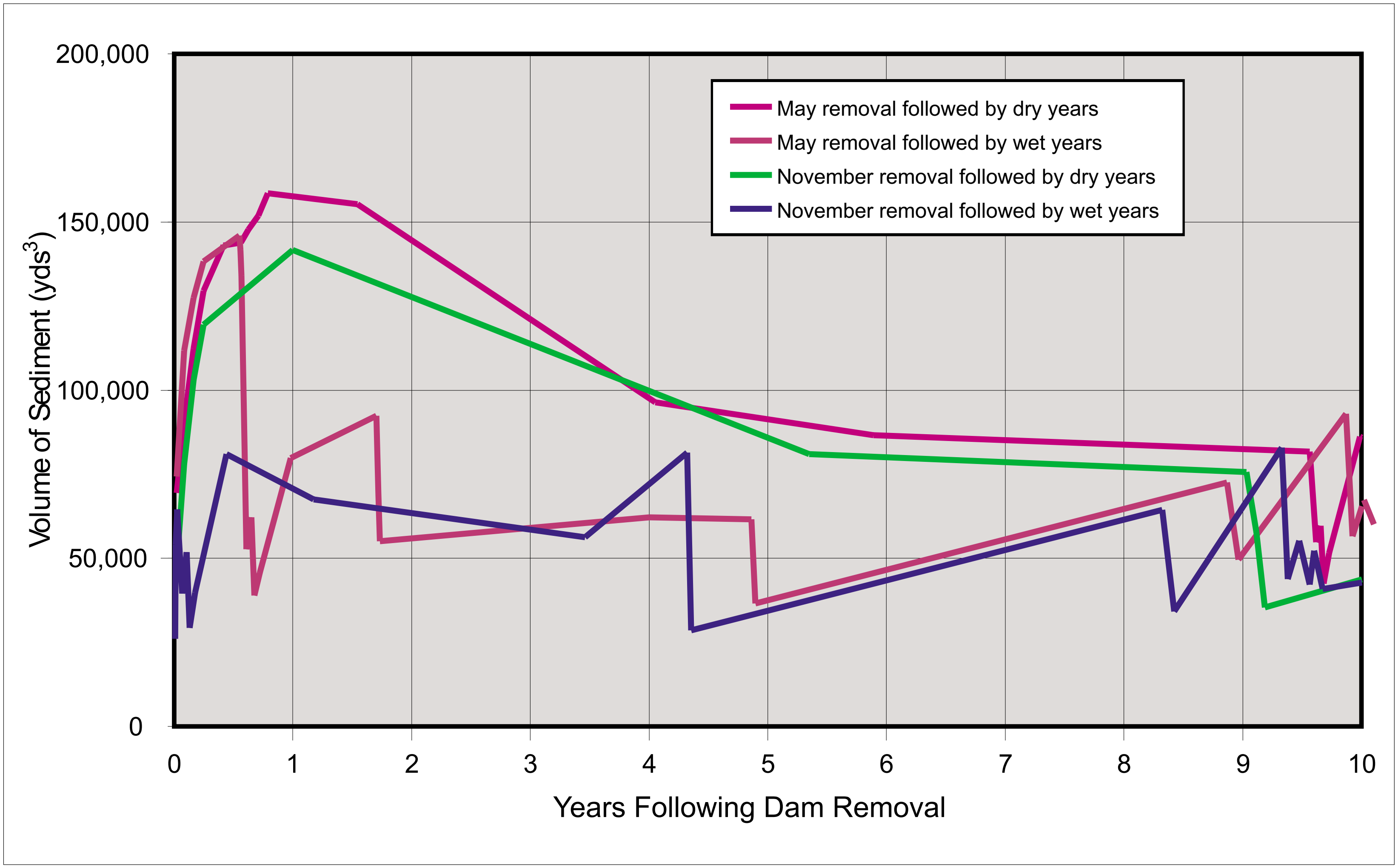

Figure 22. - This plot shows the volume of reservoir sediment deposited in river pools in the 12.5-mile reach of river downstream from the dam for each of the four dam removal scenarios. Based on these results, the reservoir sediment will temporarily deposit in river pools but will be transported downstream from the Applegate River within a 1- to 10-year period.

load would diminish in size relative to the natural sediment load carried in by the Rogue River and its two main tributaries (Applegate and Illinois).

Predicted River Channel in Savage Rapid Reservoir Following Dam Removal

Prior to the dam, a riffle existed at the dam site, and there was a pool immediately upstream (see figure 11). These river features would be restored as the sediment that currently buries them is eroded and transported downstream. If the dam were to be removed, the water surface elevation in the ½-mile reach upstream from the dam would be lowered to near the pre-dam elevation (figure 23) and would look much different from the way it looks today. However, upstream from the public boat ramp, the new water surface elevation would be essentially the same as it is today during the non-irrigation season when the stoplogs are pulled out and the reservoir is lowered to the permanent pool level.

The velocities through the dam site following a dam removal were also estimated (figure 24). Three possible scenarios were evaluated to determine if removing the entire dam versus only a portion of the dam would impact velocities. Most of the river channel south of bays 10 and 11 (where radial gates now exist) is bedrock that would still exist after removing the dam. The results show that if bays 1 through 11 were removed, velocities would never exceed 10 feet per second at flows lower than 30,000 ft^3/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream, do not typically exceed 8 feet per second.

Sediment-Related Impacts to River Infrastructures as a Result of Dam Removal

In addition to the environmental impacts resulting from periods of high sediment concentration (weight or volume of sediment transported by a stream in a unit of time) and from temporary deposition along the riverbed following dam removal, there are concerns about the impacts to specific structures located along the Rogue River downstream from the dam (attachment B). Sediment-related impacts are addressed in this study for the structures listed below:

- Two pumping plants would be constructed (one on each side of the river) immediately downstream from the dam to enable the Grants Pass Irrigation District to deliver water to its members through the irrigation canals during and after dam removal (figure 25).

- The existing Grants Pass city water treatment plant and intake structures are located about 5 miles downstream from the dam (figure 26).

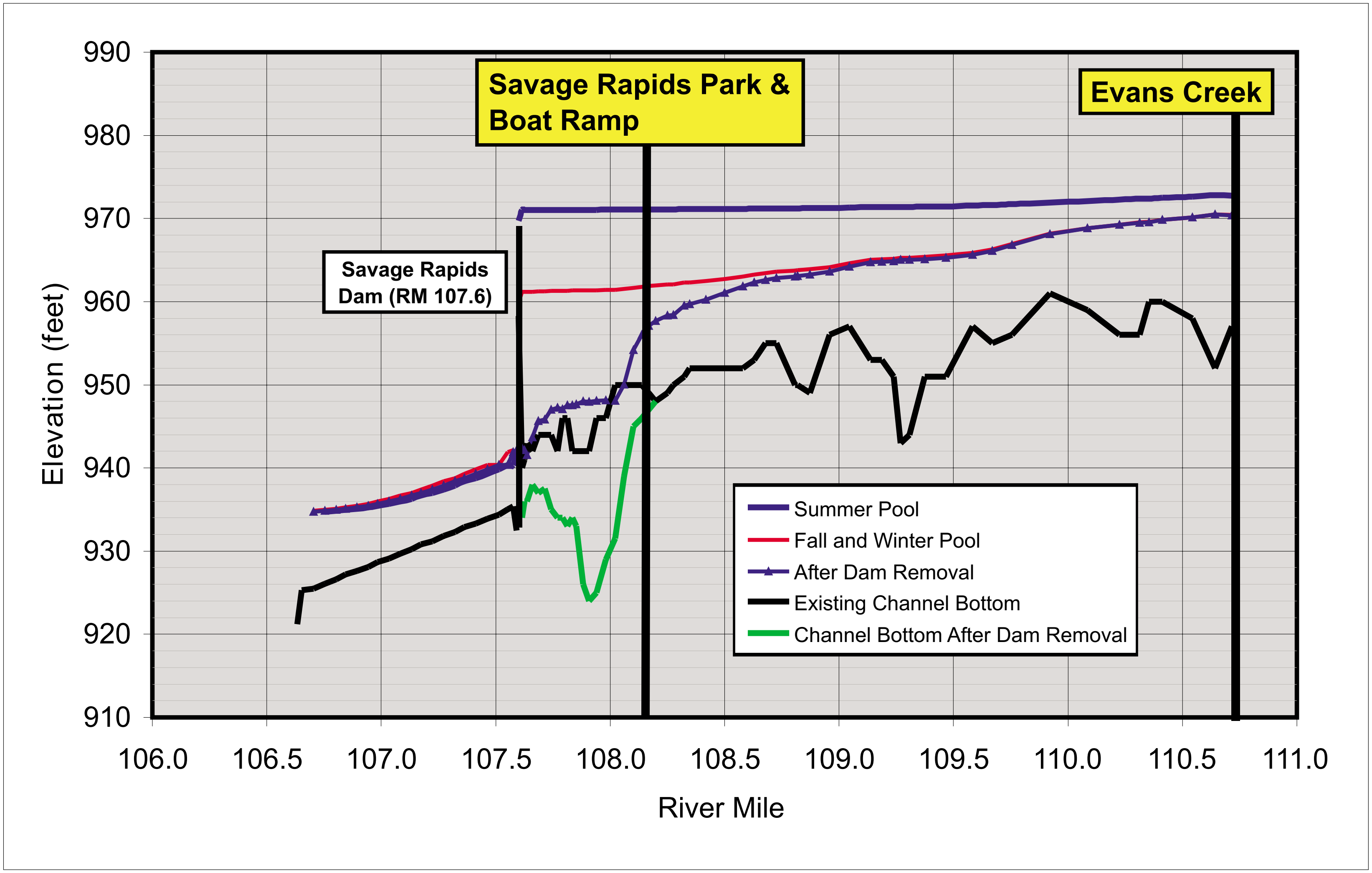

Figure 23. - This plot shows the channel bottom and water surface elevation for Savage Rapids Reservoir for both existing conditions and following dam removal. The water surface elevation and channel bottom will change significantly in the ½-mile reach upstream from the dam that is currently the permanent reservoir pool. However, upstream from the public boat ramp, the river would be essentially the same as it is today during the nonirrigation season in the fall and winter.

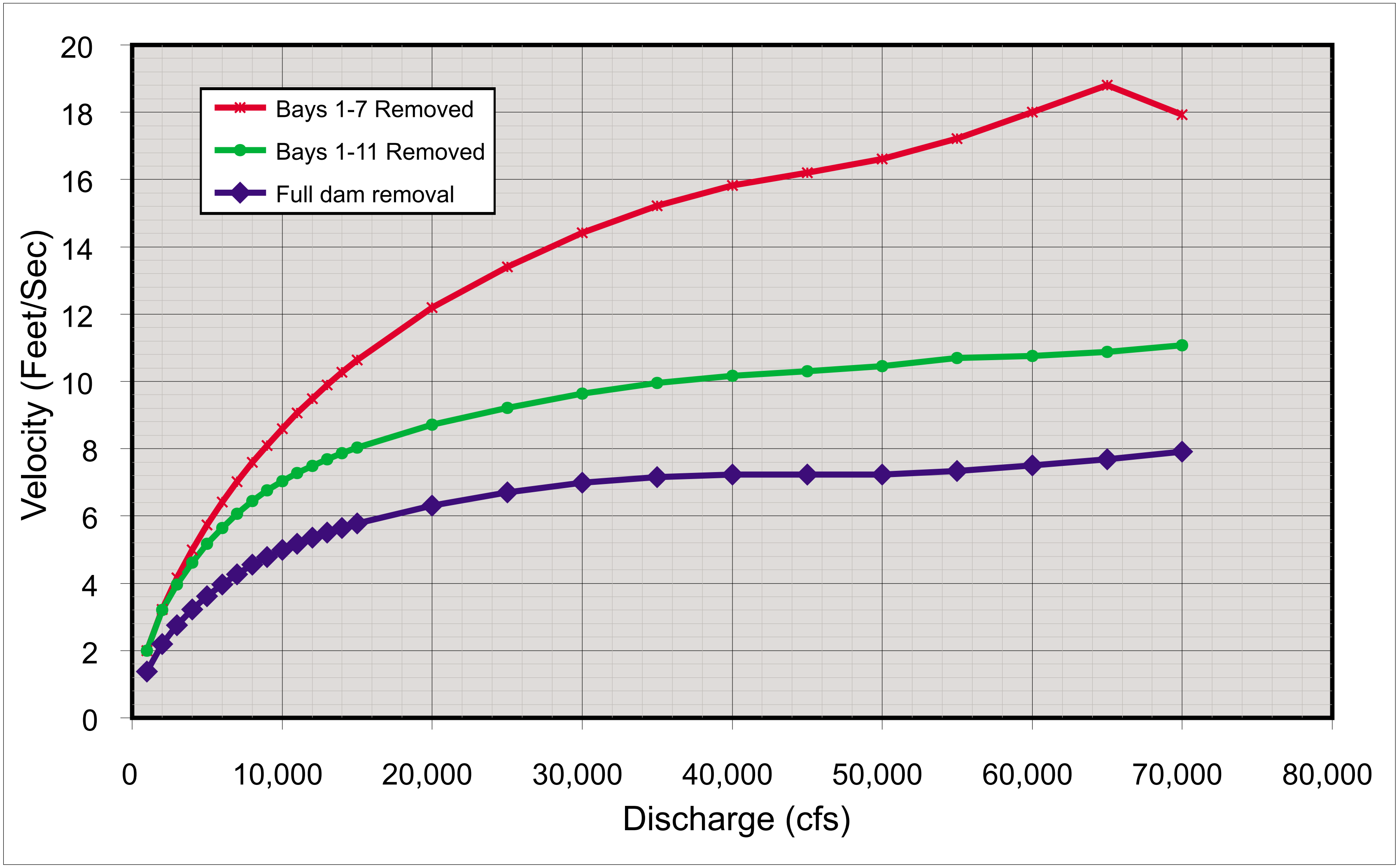

Figure 24. - This plot shows the predicted velocities at the dam site for a series of discharges for three possible dam removal options. The three options estimated were a dam removal of only bays 1-7 (in order from river right), removal of bays 1-11 (including the existing radial gates in bays 10 and 11), and removal of the entire structure.

Figure 25. - Looking downstream from Savage Rapids Dam at the proposed location of the two pumping plants which would supply water for the Grants Pass Irrigation District. One plant would be constructed on each side of the river.

Figure 26a (left) and 26b (right. - Looking at two views of the intake structure for the city of Grants Pass. The structure is located 5 miles downstream from Savage Rapids Dam on river right (looking downstream).

Irrigation Pumping Plants.—If the dam were removed during the irrigation season and the reservoir sediment were allowed to erode downstream, sediment concentrations (weight or volume of sediment transported by a stream in a unit of time) in the river channel (downstream from the dam) would be higher than normal. Because the new pumping plants would be located just downstream from the dam, there is concern that sediment would deposit around the fish screens, at the pump intake, and in the intake channels between the river and pumping plants. If coarse sediment (sands and gravels) entered the pumping plant, it could damage the pumps, through abrasion, and potentially deposit along the irrigation canals. Fine sediment (silt and clay) would not damage the pumps or deposit in the canals. The best way to eliminate or minimize these potential impacts is to prevent coarse sediment from depositing around the fish screens or entering the pumping plants. This would be accomplished by locating the pumping plants along the river channel where the river velocities are relatively high and parallel to the fish screens. A low-elevation submerged training wall could be constructed in the channel to divert coarse sediments, which are transported as bed load, away from the fish screens. Temporary dredge pumps could also be employed to remove sediment from the fish screens and pumps, if necessary.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the pumps or the irrigation canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed prior to the beginning of the next irrigation season.

After the initial flushing of the reservoir sediment, additional sediment would erode only during high-flow periods that would most likely occur during the nonirrigation season, when the pumping plants would not be in operation. During the irrigation season, riverflows and natural sediment loads would tend to be low. In fact, very little coarse sediment would be transported during the low-flow (irrigation) season. There-fore, sediment impacts on the pumping plants would be minimal after the initial flushing of reservoir sediment has occurred following dam removal.

City Water Treatment Plant Intake Structures.—As mentioned above, sediment concentrations would be greatest if the reservoir sediments are first allowed to erode and be transported downstream during the irrigation season, when riverflows tend to be low. As sediment is transported downstream by riverflows, some sediment would deposit in river pools and eddies (especially during low flows), and peak concentrations would reduce in the downstream direction. Because the Grants Pass city water treat-ment plant is located 5 miles downstream from the dam, and there are several deep pools in this reach, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

In general, getting suspended fine sediment (silt and clay) to settle out of water diverted from the river can sometimes be a difficult task for water treatment plants, especially if the concentrations are high. However, the percentage of fine sediment trapped behind

Savage Rapids Dam is very low (2 percent), so it should not pose a significant problem for the city water treatment plant. Coarse sediment would rapidly settle in the treat-ment plant, but large settling volumes would require additional dredging and disposal, and this would lead to increased labor costs. The reservoir sediment is predominantly sand (71 percent), and the volume of sand entering the treatment plant during the initial flushing of reservoir sediment would likely increase. In general, gravel-sized sediment would be too coarse to enter the treatment plant.

The amount of sand deposition within the treatment plant resulting from dam removal is difficult to predict with certainty. There are no measurements of sand transport by the Rogue River in the vicinity of the treatment plant. Also, the concentration of sand entering the treatment plant, relative to the sand concentration in the river, is not known. However, it is known that, under existing conditions, the amount of sand that enters the water treatment plant is generally between 5 to 15 yds^3 per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Most of the sand in the existing riverbed is covered by gravel. Because it takes a fairly high flow to transport gravel, sand remains trapped at low flows, and the concentrations of sand transported by the river are near zero. However, when riverflows are high enough to transport the gravel on the surface of the riverbed, the sand transport rates dramatically increase and continue to increase exponentially with additional increases in riverflow.

During the removal of Savage Rapids Dam, the reservoir sediments would begin to erode, even at low flows, in response to the higher river velocities through the former reservoir area. Sand and gravel-sized sediments would be transported downstream as a long wave, but this wave would tend to diminish because sediment particles would temporarily deposit in river pools during periods of low flow. The river pools would progressively fill (in the downstream direction) to their sediment storage capacity, resulting in a significant portion of the reservoir sediments being temporarily stored in these river pools. The sand and gravel that is transported past the river pools would eventually reach the intake structure, and sand concentrations in the river would be temporarily high. The concentrations of sand in the river would reduce as the peak of the sand wave passed the intake structure during the low-flow period. Sand concentrations would remain low until riverflows were high enough to transport the sand that would be temporarily stored in the river pools. During high riverflows, sand concentrations would be temporarily very high, but the river velocities near the intake structure would be very large relative to the velocities entering the treatment plant. This would tend to limit the concentrations of sand entering the treatment plant, thus reducing potential settling volumes.

The concentrations of sand being transported by the river vary with depth and with location across the channel. Sand concentrations are much greater near the riverbed than near the water surface and tend to be greater along the outside of river bends than along the inside of bends. The intake structure for the city water treatment plant is located on the outside of a river bend and is relatively deep in the water. However, intake structures are normally designed to minimize (to the extent possible) the entrainment of coarse sediment. For computational purposes, the concentration of sand entering the treatment plant was assumed to be equal to the mean concentration in the river. Sand transport computations for the river indicate that riverflows have to exceed 21,000 ft^3/s before gravel and sand can be transported by the river and sand concentrations are high enough to enter the treatment plant. The computed relationship between sand transport and riverflow (figure 14) was applied to the historical flow records to predict the sand concentration of the river and the concentration entering the treatment plant under existing conditions. Because this relationship does not account for the fact that the riverbed sand is covered by gravel, computed sand transport rates were set at zero when the riverflows were less than 21,000 ft^3/s. This procedure yielded a mean annual sand deposition rate in the treatment plant of 10 yds^3 per year, which matches the deposition rate experienced by the city.

Sediment model results for high-water years following dam removal indicate that 80 yds^3 of sand could deposit in the treatment plant within the first year following dam removal. Peak rates of sand deposition could exceed 10 yds^3 per day for a few days and exceed 30 yds^3 over a 1-week period (figure 27). Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 yds^3 during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

High rates of sand deposition in the treatment plant could cause rapid wear on the pumps and complicate the method of removing sand from the plant's three sedimentation basins. From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. During these months, the water treatment plant is operated at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of both fine and coarse sediment on the pumps and sedimentation basins.

There is concern that excessive deposition of coarse sediments in the vicinity of the water treatment plant could plug the intake structure. If this were to occur, a dredge would have to be employed to remove the coarse sediments. As a preventative measure, a submerged guide wall could be constructed in the channel that would force riverflows of high sediment concentration near the bed to flow past the intake structure. Surface flows of lower sediment concentration would flow over the wall and tend to flush the area around the intake structure.

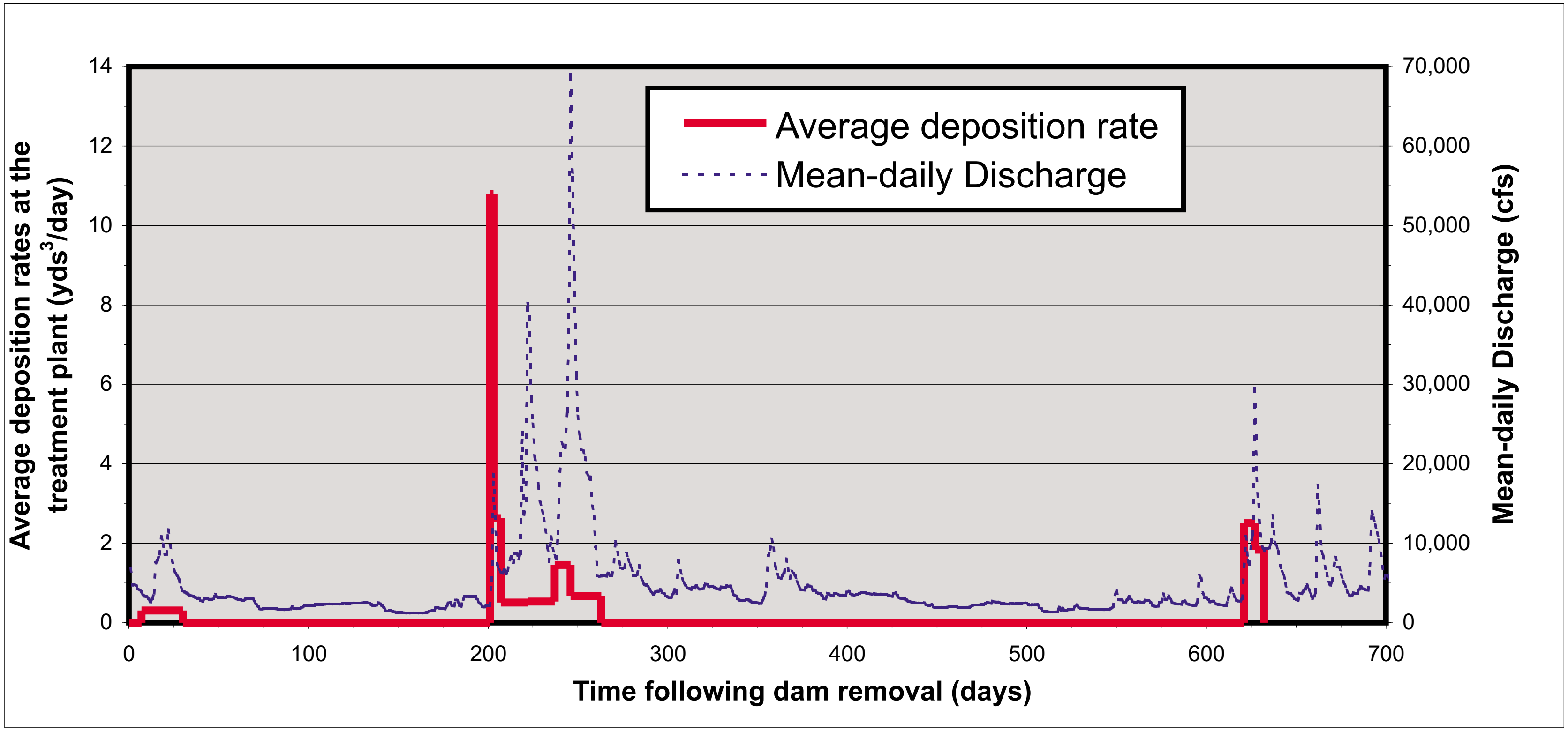

Figure 27. - Estimated deposition of sand at Grants Pass city water treatment plant following dam removal based on an assumed hydrology.

All the sediment-related impacts at the city water treatment plant can be handled, but at additional cost. These additional operating costs are difficult to estimate without knowing the future hydrology and the details of the dam removal plan but could be measured through a monitoring program. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed. Mitigation of adverse impacts that could occur at the Grants Pass city water treatment plant, or anywhere else, could be explored as part of the final design process.

Sediment Monitoring Recommendations.—This study identifies the potential sediment impacts if Savage Rapids Dam is removed. If a dam removal plan is imple-mented, the following recommendations for data collection would provide necessary information for monitoring the actual sediment impacts during and following dam removal:

- Detailed mapping of the eight deep river pools
- Sampling bed material of the eight deep river pools
- Continued measuring of discharge at the USGS gauging station
- Measuring bed load and suspended-sediment concentrations at the USGS gauging station at Grants Pass
- Continuous measuring of turbidity during and after dam removal at three locations: (1) the highway bridge at the town of Rogue River, (2) immediately downstream from Savage Rapids Dam, and (3) at the Grants Pass city water treatment plant river intake

Conclusions

This appendix describes what would happen to the sediment trapped behind Savage Rapids Dam if the dam were removed and the impacts to the river channel through the reservoir and downstream. Since the construction of Savage Rapids Dam, sediment has been trapped in Savage Rapids Reservoir. Nearly all this sediment has deposited in the ½-mile reach of the permanent reservoir pool just upstream from the dam. The sediment storage of the permanent reservoir pool is at full capacity, and likely became full within a few years after the dam was built. The volume of sediment that is trapped within the reservoir is 200,000 yds^3 (see Appendix A). This volume is roughly equivalent to two years of average annual sediment load for the Rogue River at Grants Pass, Oregon. Nearly 98 percent of sediment trapped with the reservoir is sand and gravel.

Because the reservoir contains all the sediment it can hold, sediment entering the reservoir from upstream passes through the reservoir and is transported to the downstream river reach. Both upstream and downstream from the reservoir, the river-bed surface is composed primarily of bedrock, boulders, gravel, and sand. The sand and gravel is transported primarily during winter floods and the spring snowmelt. Gravel-sized sediment is transported along the river bed (as bedload). Sand-sized sediment can be transported either as bed load or in suspension (suspended load). The reservoir is drawn down to the ½-mile-long permanent reservoir pool during the nonirrigation season to avoid flooding along the reservoir margins. During the nonirrigation season, river (rather than reservoir) conditions exist upstream from the permanent pool. During periods of high flow, velocities and turbulence increase, and the natural sediment loads of the river are transported through this reach. This is why the pools in the temporary reservoir reach have not filled with sediment.

Gravel and sand-sized sediment that is transported through the reservoir can deposit in downstream pools during low-flow periods. This coarse sediment is subsequently eroded and transported further downstream during floods. This cycle of erosion and deposition was documented at a USGS gauging station that is located in a river pool about 5 miles downstream from the dam. About 6 feet of erosion occurred along the channel bottom during a winter storm. The channel was gradually filled back in as sediment deposited during the low-flow period during the following year. The Applegate River, 12 ½ miles downstream of the dam, is the next significant contributor of sediment and water to the Rogue River. Downstream from the confluence with the Applegate River, the Rogue River passes through Hellgate Canyon, a steep, high- velocity, turbulent reach (average slope of 0.0024) that has high sediment transport capacity.

The Hec-6t (Thomas, 1996) sediment transport model was used to predict the rate at which the reservoir sediment would erode from the reservoir and the location and magnitude of deposition that might result downstream from the dam. This model was applied to the 2 ½-mile reach of reservoir and the 12 ½-mile reach of river downstream from the dam. At this time, a specific dam removal plan has not been determined. Therefore, model simulations were performed for the period immediately following dam removal. The river flows that would occur after dam removal are unknown; therefore, historic flow measurements since 1977 were used to simulate future conditions. Lost Creek Reservoir, built in 1977, regulates floods for a portion of the upstream watershed. This flood control regulation was assumed to continue in the future. Four different hydrologic scenarios were modeled based on flows measured by the USGS gaging station at Grant Pass, Oregon. The largest flood modeled was the flood that occurred in January 1997. It had a mean daily flow of 69,000 ft^3/s. Two scenarios assumed the dam would be removed in May, at the beginning of the irrigation season, and a series of either high-magnitude flow years or of low-magnitude flow years would follow the removal. The other two scenarios assumed the dam would be removed in November, at the start of the winter flood season, and either high-flow years or low-flow years would follow removal of the dam.

Savage Rapids Reservoir is only 2 to 3 times wider than the river channel. During dam removal, most of the reservoir sediment trapped behind the dam would be eroded by the river. Small amounts of sediment could remain along the margins of the lower reservoir. As the permanent reservoir pool is lowered (during dam removal), the area of the reservoir would begin to revert to river condition. This would cause an increase in flow velocity and turbulence through the reservoir area, especially in the area just upstream from the dam site. This increase in velocity and turbulence would cause the river flows to erode the reservoir sediment through headcut processes. Erosion would begin near the dam site and progressively move upstream through the reservoir sediments. This process of headcut erosion would continue until a stable slope is reached upstream from the dam site. Initially, sediment concentrations downstream from the dam would significantly increase for a short time. After the initial erosion, sediment concentrations would return to near natural levels during low-flow periods. Sediment concentrations would again increase during the first flood following dam removal. These increased sediment concentrations would gradually decline toward natural levels with each subsequent flood. Between floods, sediment concentrations would be relatively low.

Model results indicate that nearly all the 200,000 yds^3 of sediment would be eroded from the reservoir following removal of the dam. This sediment would be transported past the confluence with the Applegate River within a 1- to 10–year period, depending on the frequency and magnitude of high flows following dam removal. The 1-year period would require an extremely wet year with several high peaks following dam removal, and the 10-year period would result if several dry years with very few or no high peaks occurred following dam removal. Maximum river pool deposition in the reach between the dam and the Applegate River would range from 1 to 8 feet. The amount of deposition in downstream river pools would vary by location and time as sediment is gradually reworked downstream during floods.

After the reservoir sediment is eroded and transported past the confluence with the Applegate River, it would reach Hellgate Canyon and continue on downstream. If flood magnitudes following dam removal are high and they occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels in between floods.

Before construction of the dam, a riffle existed at the dam site, and a pool was immediately upstream from the riffle. After removal of the dam, the water surface elevation in the ½ mile reach upstream from the dam would be lowered to near the predam elevation and a riffle and pool would return. The water surface elevation in the upstream 2 miles of the reservoir would look very similar to the way it looks now during the nonirrigation season when the reservoir is drawn down.

Complete removal of the dam may not be necessary to restore river flow conditions through the dam site. There are 17 bays at the dam site. The river bed is composed of bedrock on the south (left) side (south of dam bay number 11). If the right side of the dam (bay numbers 1 through 11) were removed, model results indicate that mean flow velocities would not exceed 10 ft/s at flows up to 30,000 ft^3/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream from the dam, do not typically exceed 8 ft/s.

Two pumping plants would be constructed (one on each side of the river) immediately downstream from the existing dam site to enable the Grants Pass Irrigation District to continue to deliver water to its members after dam removal. Sediment impacts from dam removal on these two pumping plants and the City of Grants Pass water treatment plant (located 5 miles downstream) were addressed. There is a potential for deposition of coarse sediment in the vicinity of the intake structures to these pumping plants and the city water treatment plant. If this were to occur, a dredge would have to be employed to remove the coarse sediment. However, these facilities could be designed and operated to minimize the amount of sediment deposition and the associated impacts.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the irrigation pumps or the canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed before beginning the next irrigation season. The city water treatment plant operates year round. However, the city water treatment plant is located 5 miles downstream from the dam, and there are several deep pools in this reach which would trap sand and gravel-sized sediment. Therefore, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

High rates of sand deposition in the city water treatment plant could cause rapid wear on the pumps and complicate the method of removing sand from the plant's three sedimentation basins. Under existing conditions, the amount of sand that enters the water treatment plant is generally between 5 and 15 yds^3 per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Sediment model results for high-water years following dam removal indicate that 80 yd^3 of sand could deposit in the treatment plant within the first year following dam removal. Peak rates of sand deposition could exceed 10 yd^3 per day for a few days and exceed 30 yd^3 over a 1-week period (figure 27). Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 yd^3 during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. During these months, the water treatment plant is operated at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of both fine and coarse sediment on the pumps and sedimentation basins.

All the sediment-related impacts at the pumping plant and the city water treatment plant could be handled, but at additional cost. These additional operating costs are difficult to estimate before dam removal without knowing the future hydrology and the details of the dam removal plan. Sediment impacts could be measured through a monitoring program during dam removal to document the impacts. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed.

The authors recommend that a monitoring program be implemented if the dam is removed. The monitoring would provide necessary information for evaluating the sediment impacts to the river channel and downstream infrastructure.

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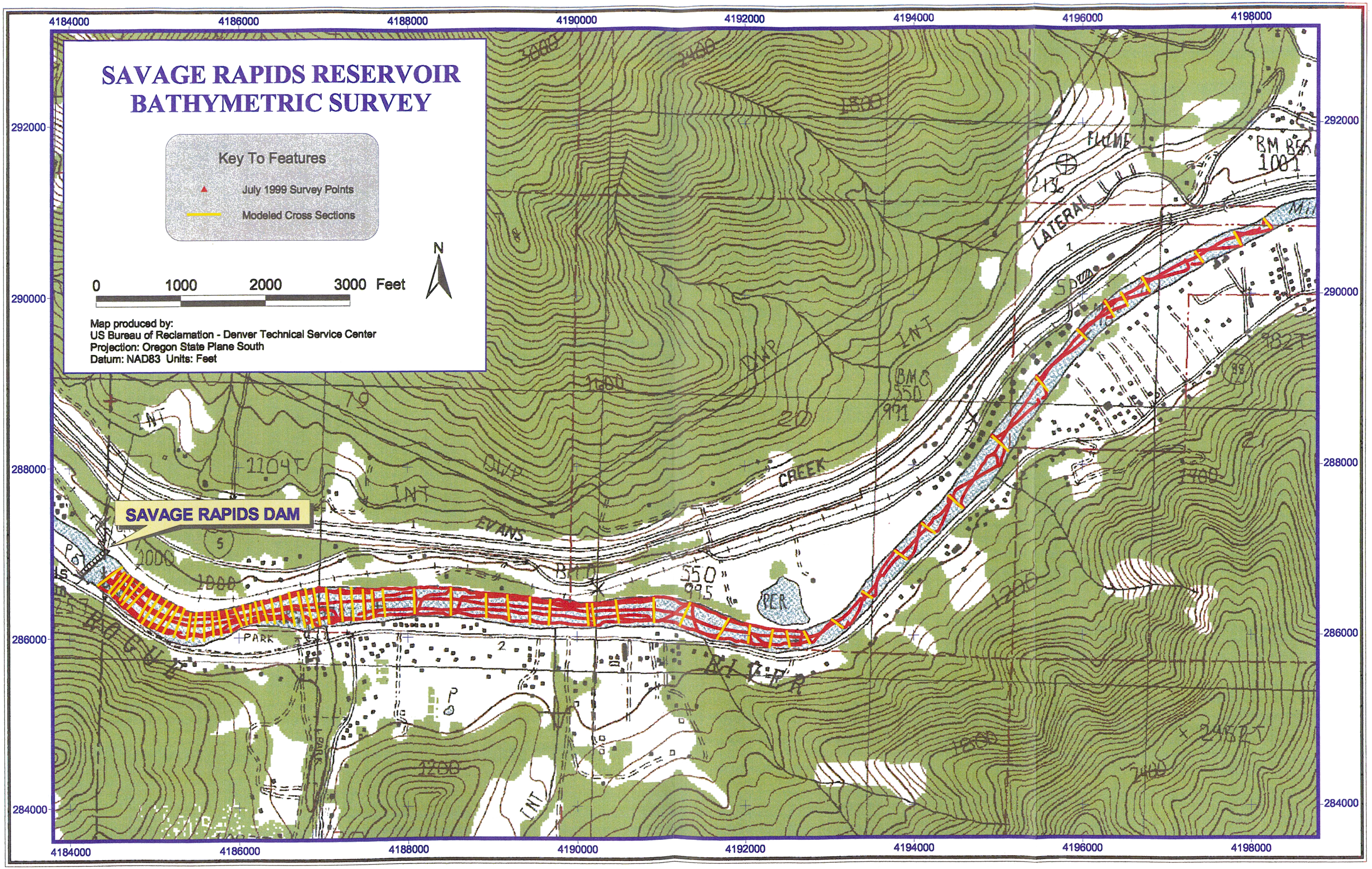
Attachment A

BATHYMETRIC SURVEY DATA OF SAVAGE RAPIDS RESERVOIR AND CROSS SECTION LOCATIONS


SAVAGE RAPIDS RESERVOIR
BATHYMETRIC SURVEY
Key To Features
July 1999 Survey Points
Modeled Cross Sections
0
1000
2000
3000
Feet
N
Map produced by:
US Bureau of Reclamation - Denver Technical Service Center
Projection: Oregon State Plane South
Datum: NAD83 Units: Feet
SAVAGE RAPIDS DAM
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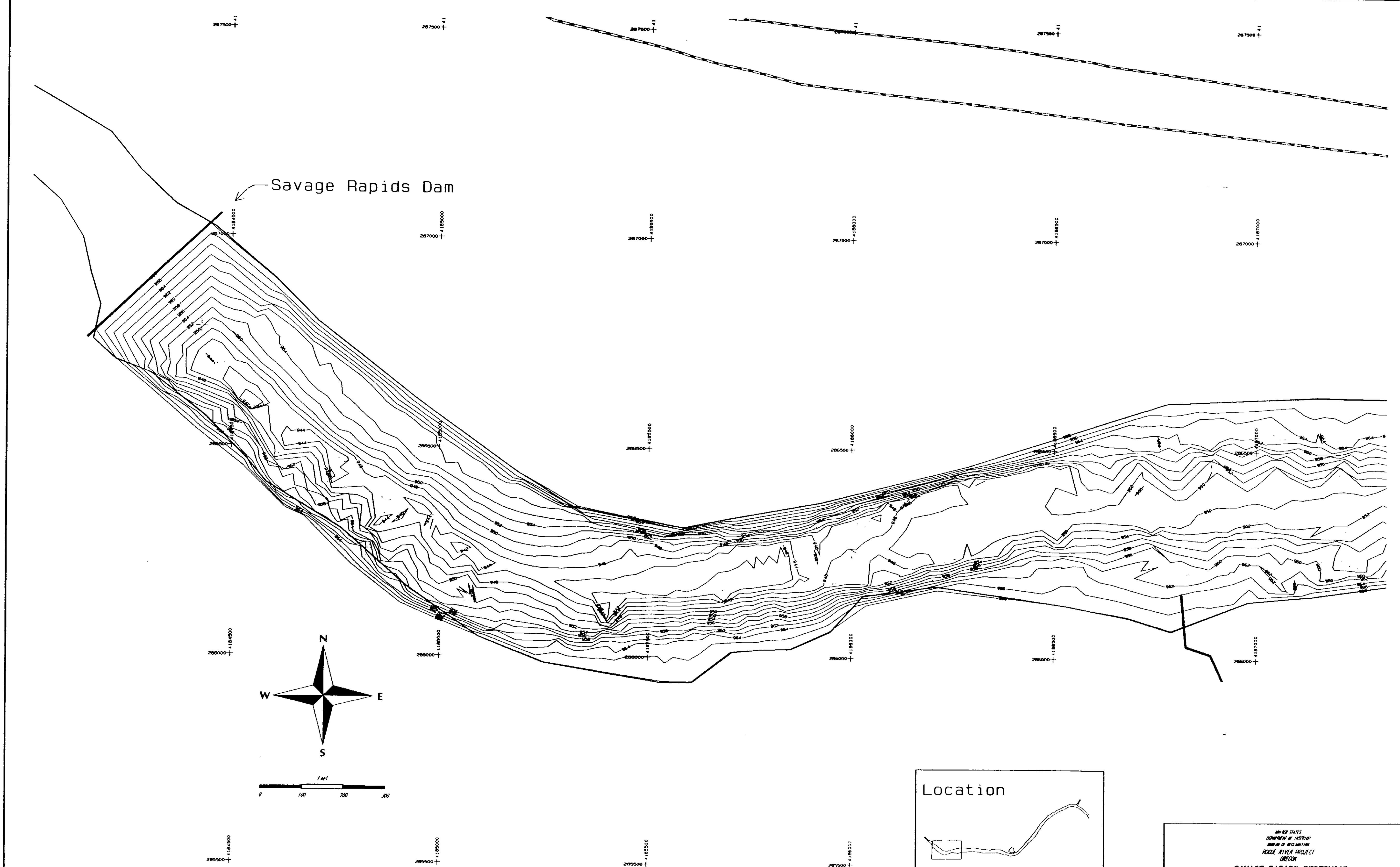
4186000
4188000
4190000
4192000
4194000
4196000
4198000
292000
290000
288000
286000
284000
EVANS
CREEK
LATERAL
FLUME
PARK

Attachment B

2-FOOT CONTOUR MAP OF
SAVAGE RAPIDS RESERVOIR



ROGUE RIVER PROJECT
OREGON

SAVAGE RAPIDS RESERVOIR
Two Foot Contours

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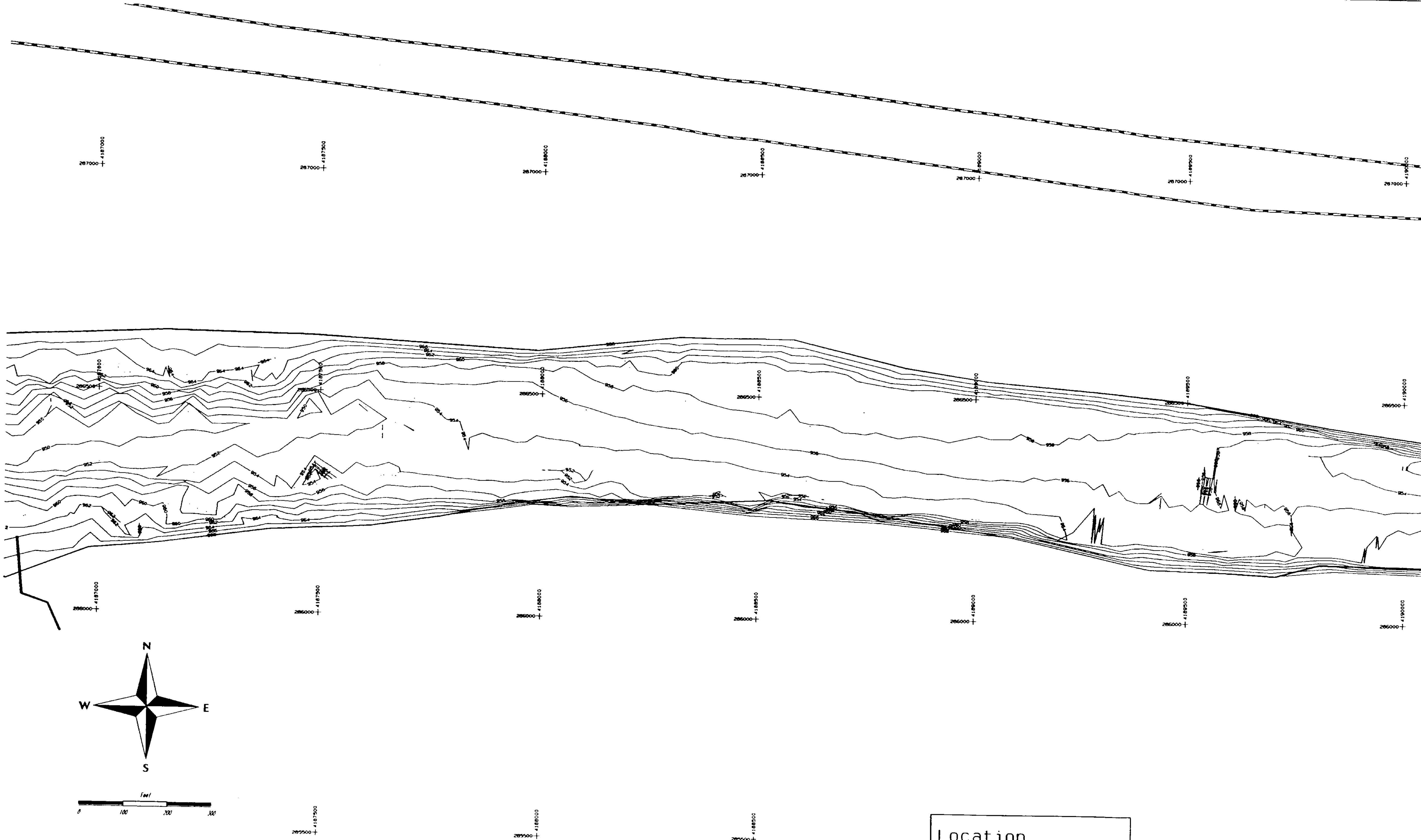
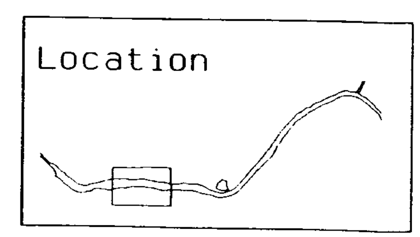
CHECKED BY______________ APPROVED______________
Group Manager

Denver, Colorado DEC 07, 2000 | 1





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SAVAGE RAPIDS RESERVOIR

Two Foot Contours

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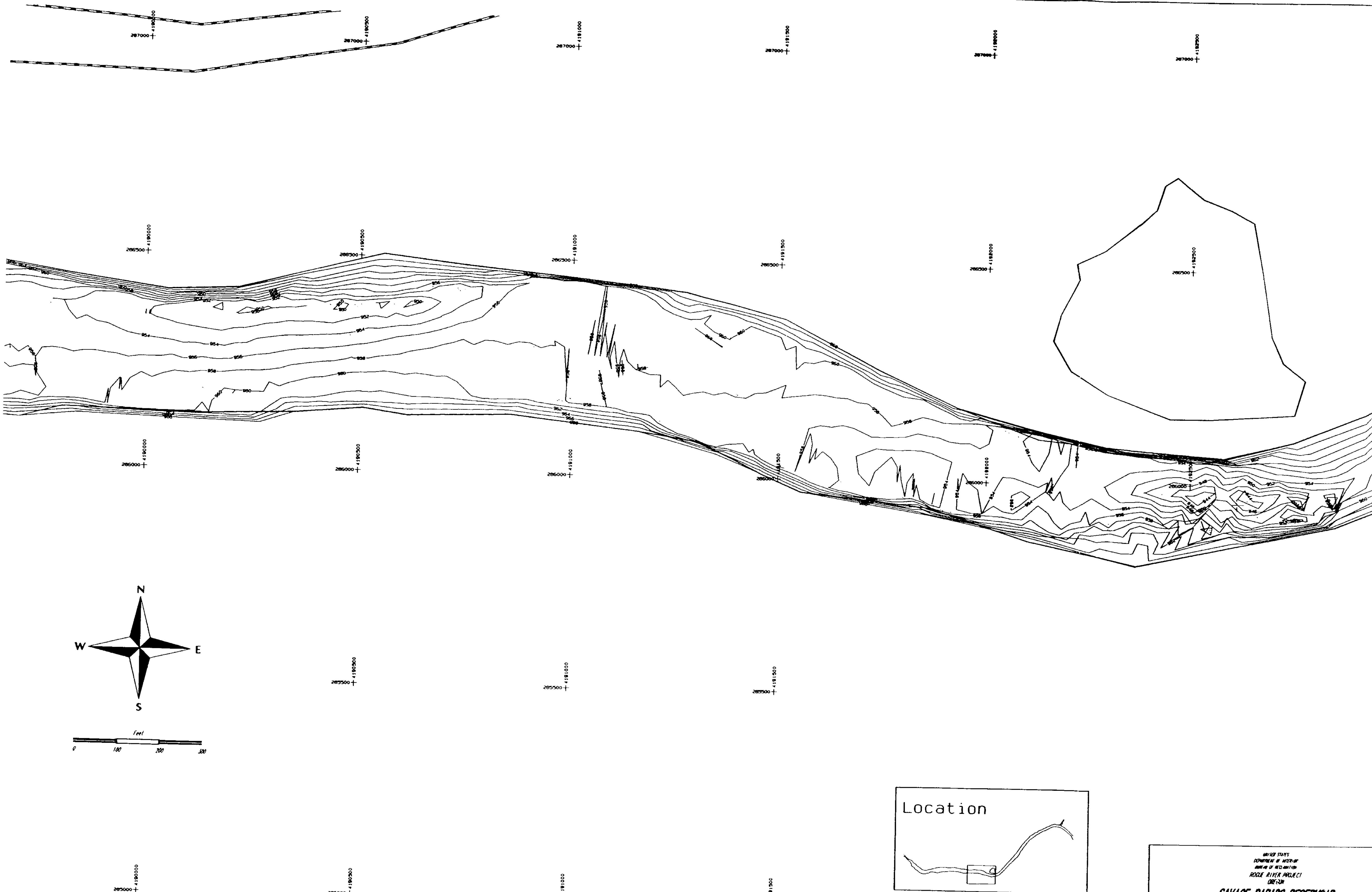

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SAVAGE RAPIDS RESERVOIR

Two Foot Contours

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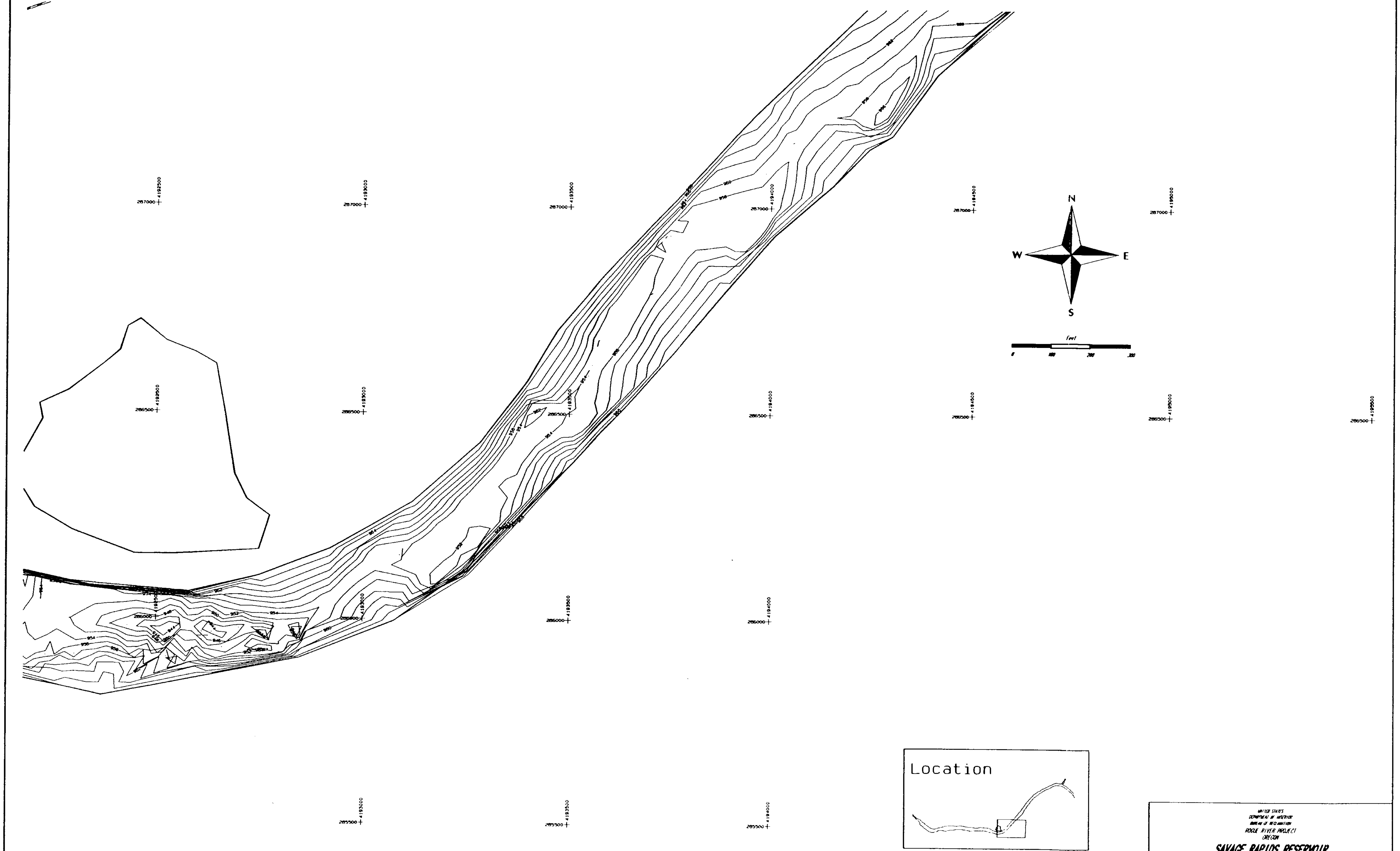

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SAVAGE RAPIDS RESERVOIR

Two Foot Contours

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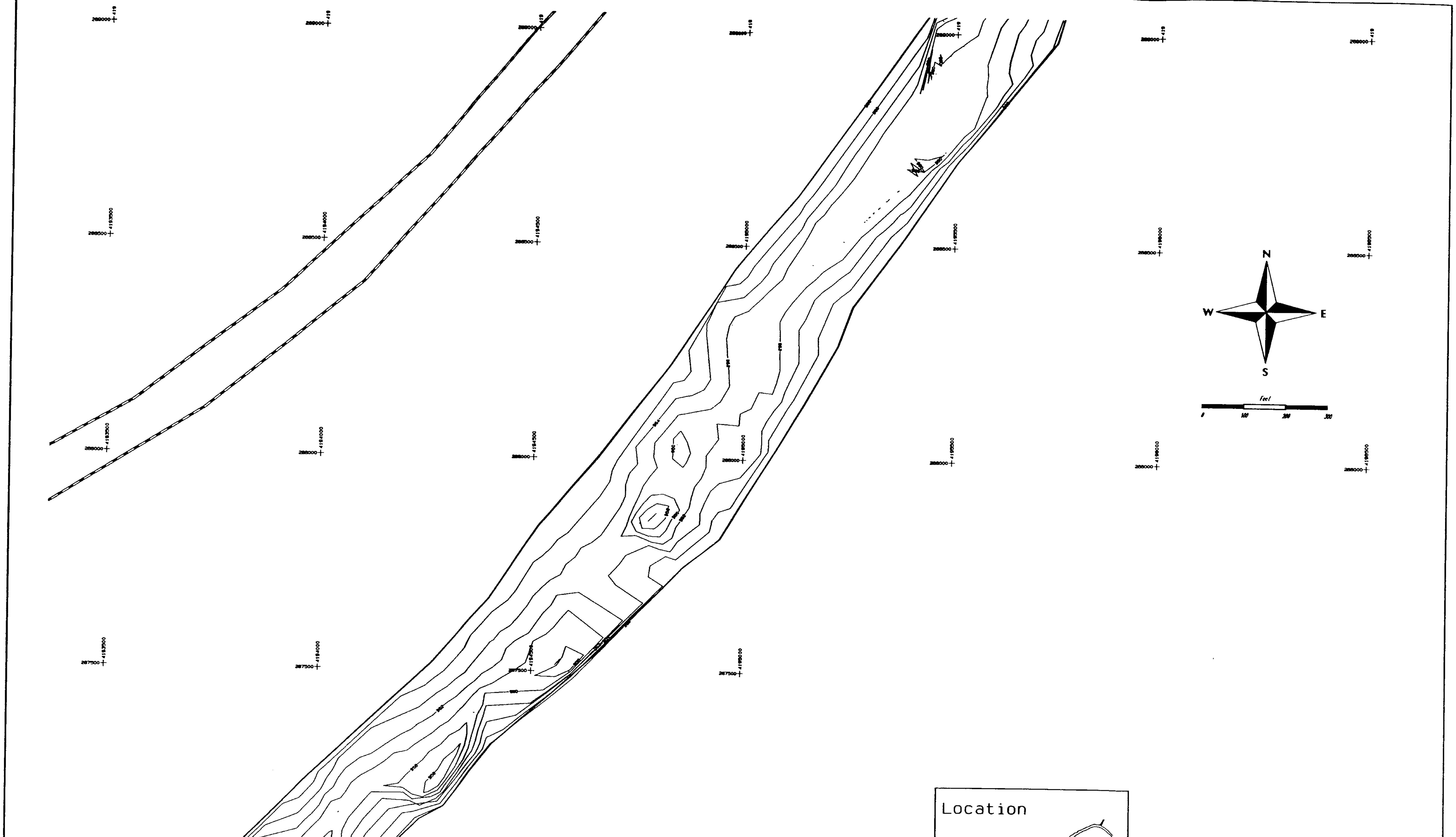

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SAVAGE RAPIDS RESERVOIR

Two Foot Contours

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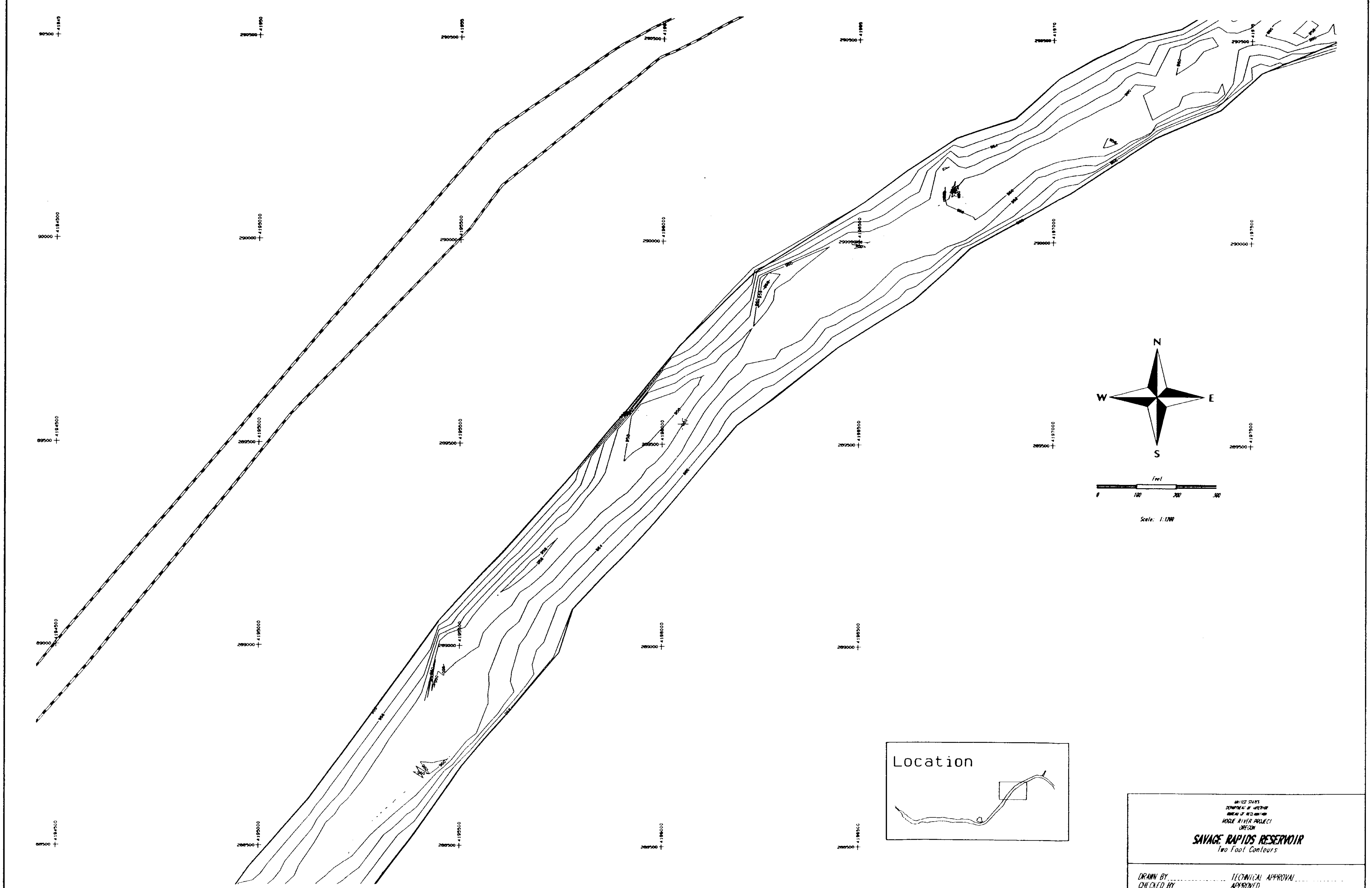
Group Manager

Denver, Colorado DEC 07, 2000 | 5



ROGUE RIVER PROJECT
OREGON

SAVAGE RAPIDS RESERVOIR
Two Foot Contours

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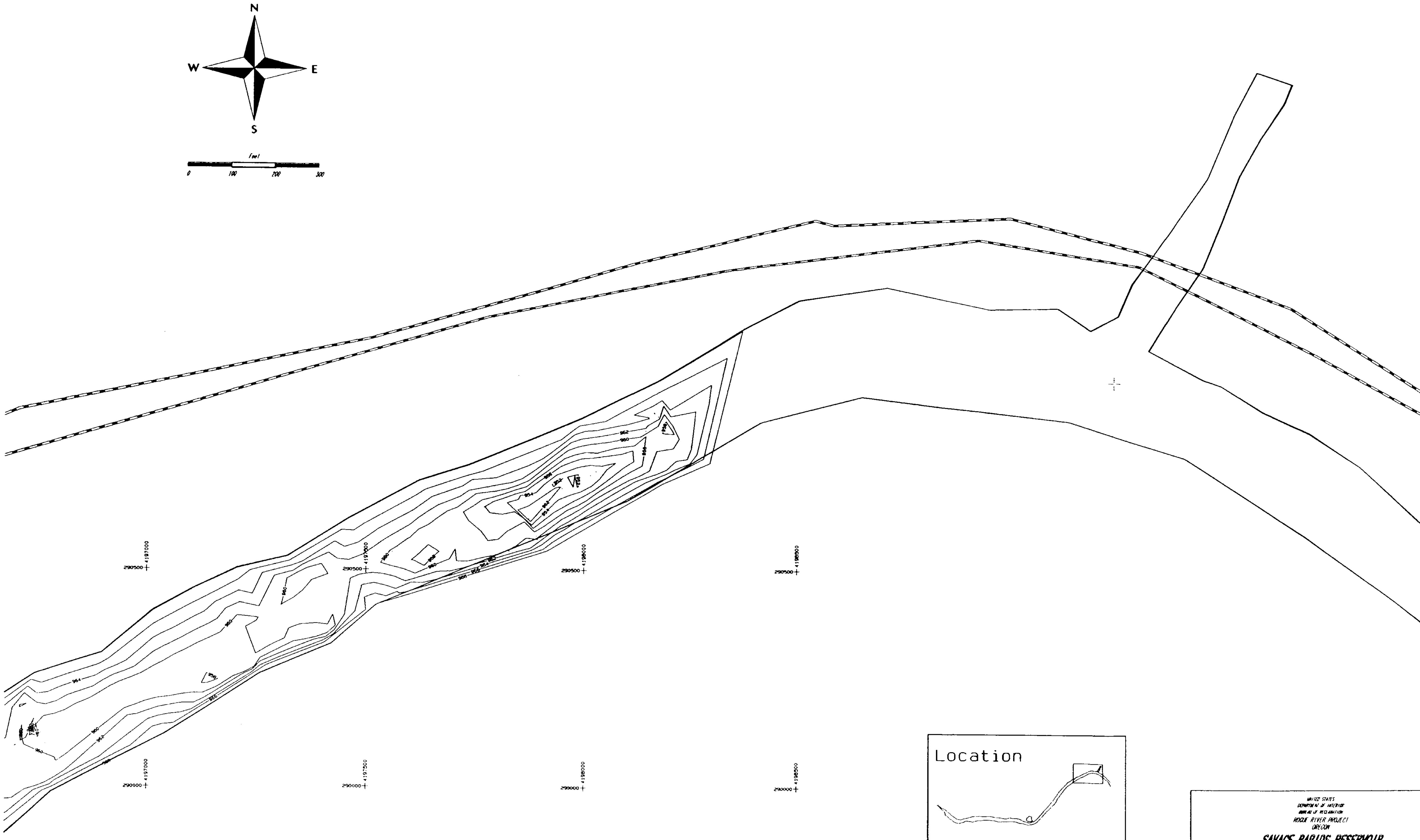
Denver, Colorado DEC 07, 2000 | 6



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SAVAGE RAPIDS RESERVOIR

Two Foot Contours

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CHECKED BY .... APPROVED ....
Group Manager

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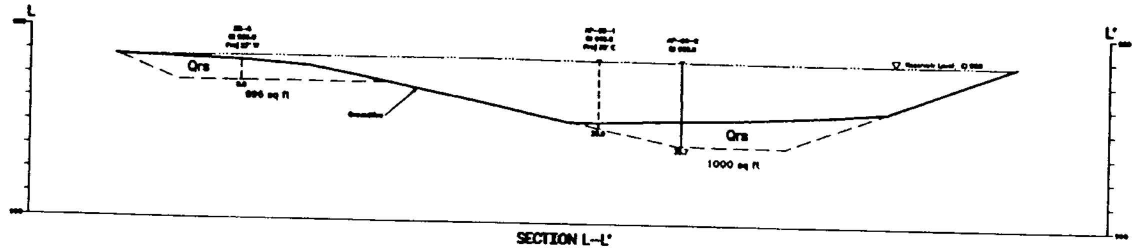

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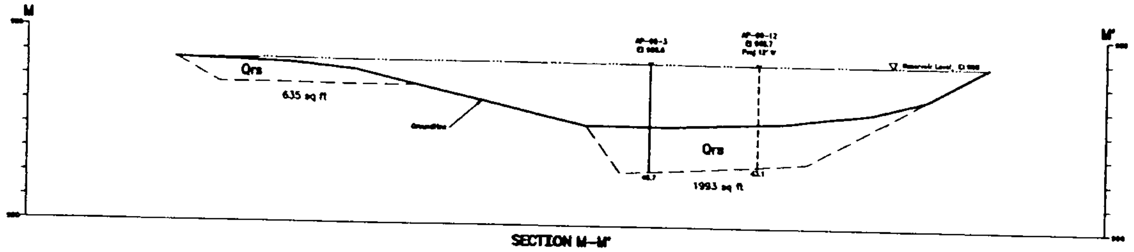

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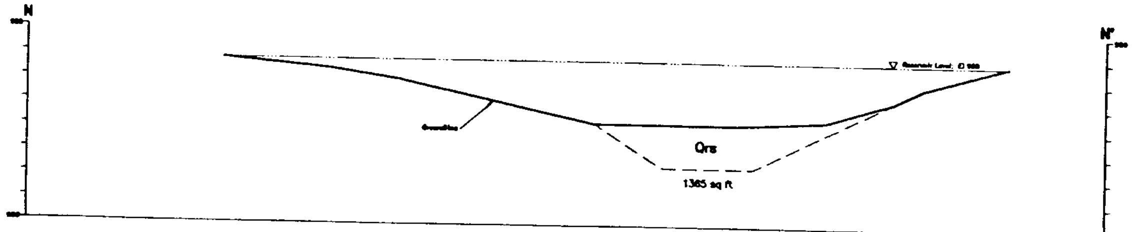

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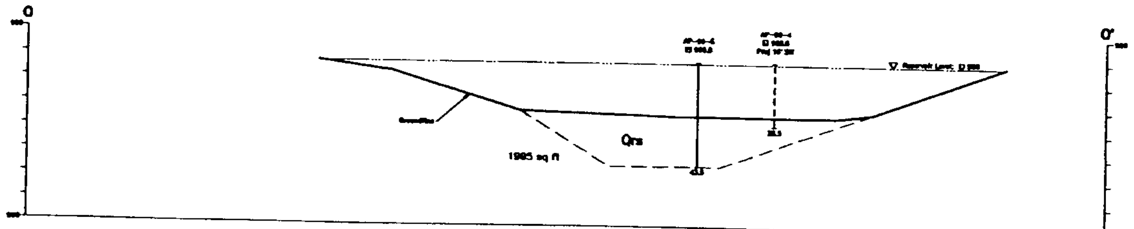

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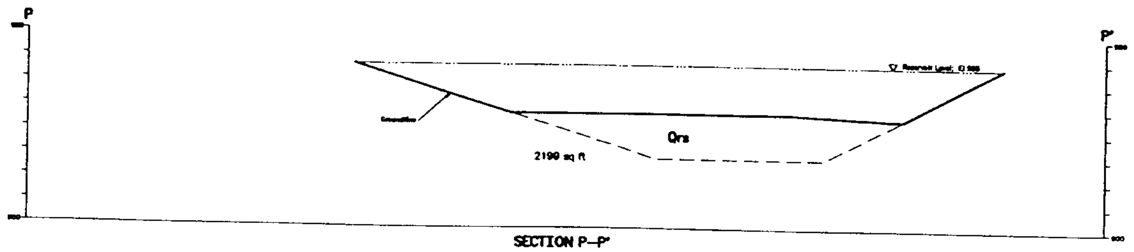

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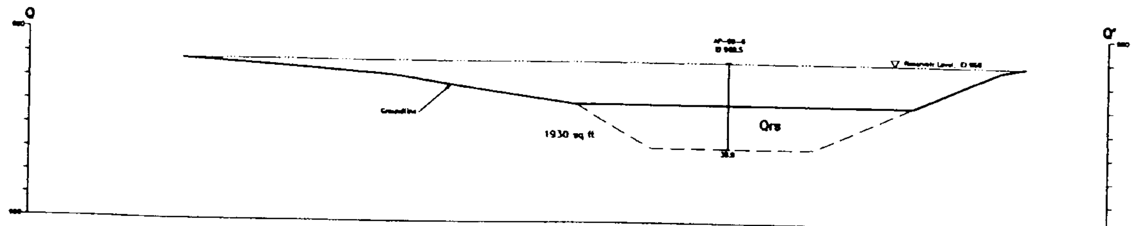

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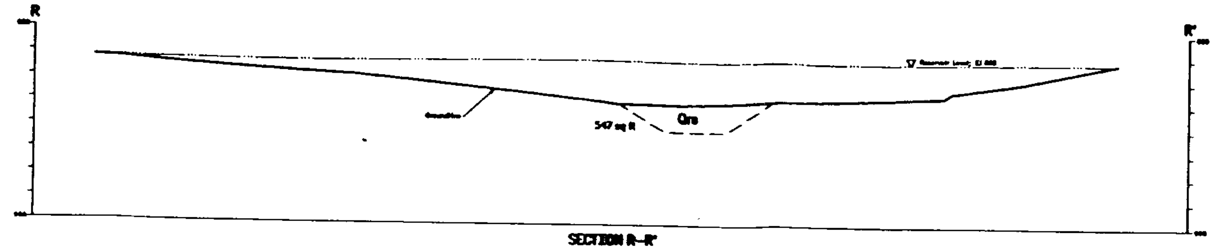

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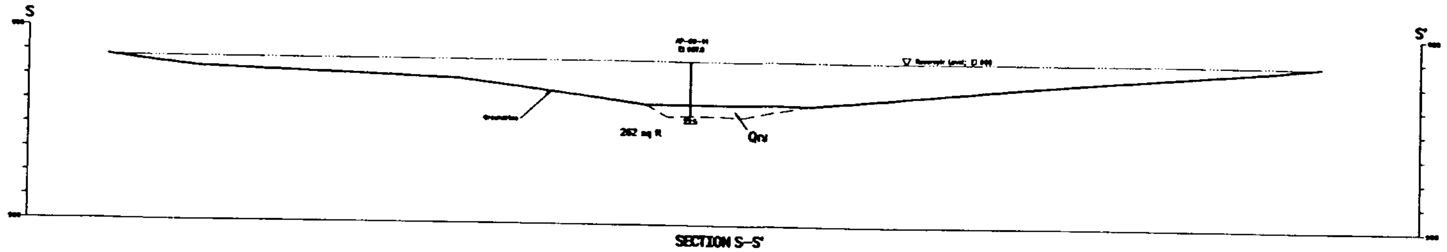

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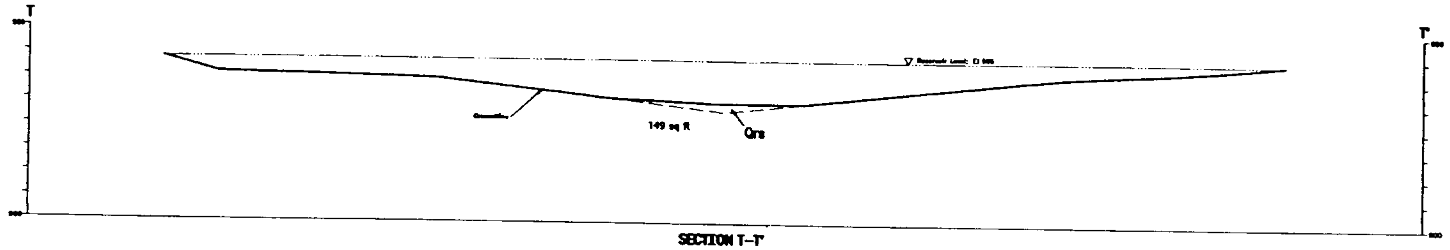

SECTION T–T'

Notes:

1. Refer to dwg 448-100-16 for General Geologic Explanation, Legend and Notes.
2. Refer to dwg 448-100-17 for locations of cross sections and explorations.

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SCALE OF FEET

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
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ROGUE RIVER BASIN PROJECT – OREGON

SAVAGE RAPIDS DAM
SEDIMENTATION STUDY
GEOLOGIC SECTIONS L–L' THROUGH T–T'

GEOLOGY R. LINK
DRAWN T. ENGLAND TECH. APPROVAL
CHECKED APPROVED
PROGRAM MANAGER

CADD SYSTEM ACAD v14 | CADD FILENAME | DATE PLOTTED 4-11-00
BOISE, IDAHO | NOVEMBER 1999 | SHEET 1 OF 1
448-100-19

Attachment C

HYDRAULIC PARAMETERS FROM
CALIBRATION MODEL RUNS

Attachment C for Appendix B:

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
		RIVER DISCHARGE: 3,866 cfs				
Upstream End of Survey	110.72	957.0	969.2	12.2	3	130
	110.64	952.0	969.2	17.2	2	190
	110.54	958.0	969.1	11.1	2	180
	110.41	960.0	969.0	9.0	2	210
	110.35	960.0	968.9	8.9	2	200
	110.31	956.0	968.9	12.9	2	240
	110.22	956.0	968.8	12.8	2	180
	110.08	959.0	968.7	9.7	2	230
	109.92	961.0	968.6	7.6	2	280
	109.76	956.0	968.4	12.4	2	240
	109.67	955.0	968.4	13.4	2	220
	109.58	957.0	968.3	11.3	2	200
	109.47	951.0	968.3	17.3	2	160
	109.38	951.0	968.3	17.3	1	180
	109.31	944.0	968.3	24.3	1	160
	109.27	943.0	968.3	25.3	1	180
	109.24	951.0	968.3	17.3	1	200
	109.19	953.0	968.2	15.2	1	230
	109.14	953.0	968.2	15.2	1	290
	109.04	957.0	968.2	11.2	1	320
	108.96	956.0	968.2	12.2	1	310
	108.87	949.0	968.2	19.2	1	290
	108.82	950.0	968.2	18.2	1	280
	108.81	950.0	968.2	18.2	1	280
	108.73	955.0	968.2	13.2	1	320
	108.68	955.0	968.2	13.2	1	330
	108.63	953.0	968.2	15.2	1	320
	108.58	952.0	968.1	16.1	1	300
	108.50	952.0	968.1	16.1	1	340
	108.42	952.0	968.1	16.1	1	310
	108.35	952.0	968.1	16.1	1	340
	108.32	951.0	968.1	17.1	1	350
	108.28	950.0	968.1	18.1	1	410
	108.25	949.0	968.1	19.1	1	370
	108.20	948.0	968.1	20.1	1	410
	108.17	949.0	968.1	19.1	1	440
	108.14	950.0	968.1	18.1	1	484
	108.10	950.0	968.1	18.1	1	524
	108.06	950.0	968.1	18.1	1	443
	108.02	950.0	968.1	18.1	1	351
	107.98	946.0	968.1	22.1	1	271
	107.94	946.0	968.1	22.1	1	287

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	107.91	942.0	968.1	26.1	1	328
	107.88	942.0	968.1	26.1	1	340
	107.85	942.0	968.1	26.1	1	376
	107.83	942.0	968.1	26.1	1	378
	107.81	946.0	968.1	22.1	1	379
	107.79	946.0	968.1	22.1	1	396
	107.77	942.0	968.1	26.1	1	413
	107.74	944.0	968.1	24.1	1	413
	107.71	944.0	968.1	24.1	1	391
	107.69	944.0	968.1	24.1	1	389
	107.66	942.0	968.1	26.1	1	386
	107.64	943.0	968.1	25.1	1	398
	107.62	941.0	968.1	27.1	1	400
	107.62	940.0	968.1	28.1	0	437
Savage Rapids Dam	107.60	958.3	964.7	6.4	14	44
	107.59	933.0	939.9	6.9	3	225
	107.58	932.5	939.7	7.2	4	224
	107.55	935.4	938.8	3.4	7	167
	107.51	935.0	938.4	3.4	4	266
	107.46	934.4	937.9	3.5	4	265
	107.41	933.9	937.3	3.4	4	263
	107.36	933.3	936.8	3.5	4	263
	107.32	932.9	936.4	3.5	4	262
	107.27	932.3	935.8	3.5	4	261
	107.22	931.8	935.3	3.5	4	260
	107.17	931.2	934.7	3.5	4	259
	107.13	930.8	934.3	3.5	4	258
	107.08	930.2	933.8	3.6	4	258
	107.03	929.7	933.3	3.6	4	257
	106.98	929.1	932.9	3.8	4	257
	106.94	928.7	932.6	3.9	4	258
	106.89	928.1	932.3	4.2	4	258
	106.84	927.6	932.0	4.4	3	259
	106.80	927.2	931.8	4.6	3	260
	106.75	926.6	931.7	5.1	3	261
	106.70	926.1	931.6	5.5	3	262
	106.65	925.5	930.5	5.0	7	111
	106.63	925.3	928.8	3.5	11	107
	106.50	921.2	927.3	6.1	2	260
	106.49	921.0	927.3	6.2	2	260
	106.46	921.4	925.9	4.5	9	182
	106.41	916.3	925.8	9.5	4	135
	106.30	915.4	925.7	10.3	3	142
	106.26	916.3	925.6	9.3	3	140

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	106.23	911.1	924.6	13.5	8	75
	106.20	906.0	925.0	19.0	4	108
	106.18	910.8	923.7	13.0	9	67
	106.04	894.2	924.5	30.3	1	172
	105.94	904.2	924.4	20.2	2	165
	105.89	907.9	924.3	16.4	3	163
	105.83	919.0	924.0	5.1	4	231
	105.80	920.0	923.0	3.0	7	266
	105.74	915.2	919.6	4.4	8	202
	105.70	914.0	916.7	2.7	9	161
	105.66	901.5	915.9	14.4	4	141
	105.62	894.7	915.9	21.2	3	142
	105.60	887.6	915.9	28.4	1	199
	105.58	884.1	915.9	31.9	1	187
	105.56	888.2	915.9	27.7	1	192
	105.54	893.1	915.9	22.9	2	215
	105.51	905.5	915.8	10.3	3	179
	105.48	907.3	915.7	8.4	3	161
	105.45	910.0	913.8	3.8	11	102
	105.37	877.2	912.2	35.0	1	205
	105.32	898.7	912.1	13.4	3	163
	105.28	906.0	911.5	5.5	6	151
	105.23	905.0	910.9	5.9	5	237
	105.19	900.6	910.8	10.2	4	134
	105.16	901.6	910.6	9.0	5	138
	105.13	903.8	909.8	6.0	7	112
	105.10	904.0	909.0	5.0	8	123
	105.07	901.4	908.9	7.5	5	123
	105.04	898.7	908.8	10.1	4	142
	105.00	893.0	908.8	15.9	3	170
	104.96	894.4	908.7	14.3	3	163
	104.94	900.7	908.7	8.0	3	212
	104.91	903.7	908.3	4.6	5	185
	104.84	900.0	908.2	8.1	3	194
	104.74	899.4	907.8	8.4	4	167
	104.69	898.2	907.8	9.6	2	217
	104.59	897.2	907.5	10.4	4	194
	104.52	898.7	907.3	8.6	4	181
	104.44	897.6	907.3	9.7	2	221
	104.39	902.1	906.8	4.7	5	227
	104.36	903.1	905.2	2.1	8	231
	104.33	897.9	903.3	5.4	7	177
	104.30	894.0	903.5	9.5	3	205
	104.20	894.8	903.1	8.4	3	203

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	104.16	893.7	903.1	9.4	3	212
	104.11	894.9	903.0	8.1	3	209
	104.04	895.3	902.9	7.6	3	196
	103.91	893.9	902.5	8.6	3	210
	103.84	892.7	902.3	9.6	3	187
	103.80	894.6	901.9	7.3	5	177
	103.79	890.7	902.0	11.3	3	174
	103.78	893.1	901.9	8.8	4	189
	103.77	892.7	901.9	9.2	4	195
	103.74	894.2	901.4	7.3	5	184
	103.71	896.5	900.1	3.6	8	164
	103.70	894.0	900.4	6.4	4	179
	103.69	891.6	900.5	8.9	3	179
	103.67	889.1	900.5	11.4	3	169
	103.64	891.2	900.3	9.2	3	188
	103.56	890.9	900.3	9.4	2	217
	103.52	890.8	900.3	9.5	3	217
	103.47	891.8	900.2	8.3	3	216
	103.45	892.0	900.1	8.1	3	216
	103.39	893.0	899.9	6.9	3	214
	103.34	893.0	899.5	6.5	5	213
	103.29	892.0	898.7	6.7	5	201
	103.24	895.0	897.5	2.5	6	261
	103.19	890.5	897.6	7.1	2	250
	103.14	893.0	897.2	4.2	5	223
	103.08	887.2	897.3	10.2	2	246
	103.07	884.6	897.3	12.7	2	252
	103.06	875.3	897.3	22.1	1	242
	103.02	888.2	897.3	9.1	2	251
	102.97	890.4	897.2	6.7	3	254
	102.93	891.8	897.0	5.2	3	261
	102.88	892.0	896.5	4.5	5	262
	102.77	891.4	895.9	4.4	3	290
	102.68	890.9	894.8	3.9	5	258
	102.60	888.4	894.2	5.9	4	234
	102.51	885.2	894.1	8.9	3	242
	102.44	886.3	893.9	7.6	3	223
	102.36	887.5	893.7	6.2	3	229
	102.28	890.1	892.2	2.1	8	237
	102.17	881.0	888.8	7.8	3	182
	102.06	866.5	888.9	22.4	1	256
	102.04	882.4	888.6	6.3	4	265
	102.03	880.4	888.7	8.3	2	299
	101.85	881.1	888.4	7.3	2	313

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
		RIVER DISCHARGE: 3,866 cfs				
	101.77	880.6	888.2	7.7	2	338
	101.72	879.8	888.2	8.4	2	341
	101.72	879.7	888.2	8.5	2	332
	101.72	879.6	888.2	8.6	2	332
	101.71	879.6	888.2	8.6	2	342
	101.70	879.7	888.2	8.5	2	341
	101.67	880.0	888.0	8.1	3	201
	101.64	879.9	888.0	8.2	2	255
	101.63	879.9	888.0	8.1	2	255
	101.61	879.9	888.0	8.1	2	254
	101.60	879.9	887.9	8.1	3	255
	101.60	879.8	887.9	8.2	2	292
	101.58	879.6	887.9	8.4	2	282
	101.53	881.8	887.7	5.9	3	289
	101.43	883.0	887.3	4.3	3	333
	101.40	881.9	886.1	4.2	8	271
	101.32	880.3	884.1	3.8	4	279
	101.28	877.9	884.1	6.3	2	327
	101.20	871.7	884.1	12.3	2	261
	101.13	875.4	883.7	8.3	4	198
	101.06	878.0	881.7	3.7	8	243
	101.05	875.6	881.2	5.6	5	161
	101.04	874.2	881.2	7.0	4	152
	101.02	872.8	881.2	8.4	4	144
	101.01	871.4	881.2	9.8	3	172
	100.98	866.0	881.2	15.2	2	166
	100.96	872.0	881.1	9.0	3	165
	100.91	871.9	880.9	9.0	3	164
	100.89	873.5	880.6	7.1	5	131
	100.88	875.0	880.3	5.3	6	153
	100.86	872.2	880.3	8.2	4	146
	100.84	867.4	880.4	13.0	3	157
	100.78	873.0	880.0	7.0	4	148
	100.73	875.0	879.2	4.2	6	274
	100.69	874.5	878.7	4.2	4	251
	100.65	874.0	878.1	4.0	5	219
	100.61	871.6	877.6	6.0	4	195
	100.56	869.2	877.5	8.4	3	204
	100.45	869.0	877.3	8.3	3	205
	100.44	865.4	877.3	11.9	2	212
	100.43	870.4	877.2	6.8	3	246
	100.37	868.8	877.1	8.3	2	260
	100.30	870.0	876.6	6.6	5	139
	100.27	871.5	876.4	4.9	5	188

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	100.24	871.5	876.2	4.6	4	208
	100.23	871.3	875.5	4.2	7	179
	100.22	870.6	875.3	4.8	6	172
	100.21	869.9	875.2	5.4	6	169
	100.20	869.1	875.2	6.0	5	167
	100.19	868.4	875.1	6.7	5	165
	100.18	867.7	875.1	7.4	4	164
	100.17	867.0	875.1	8.1	4	162
	100.10	862.4	874.9	12.5	4	128
	100.02	864.0	874.8	10.8	3	166
	99.94	865.6	874.7	9.1	3	194
	99.82	866.1	874.5	8.5	3	209
	99.79	866.1	874.4	8.3	3	205
	99.73	867.6	874.2	6.6	3	196
	99.64	867.5	873.9	6.5	3	224
	99.55	868.1	873.2	5.2	5	172
	99.42	867.0	872.8	5.8	3	240
	99.31	866.9	872.0	5.1	5	193
	99.20	864.7	871.0	6.3	4	211
	99.07	864.1	870.0	5.9	4	216
	98.96	862.5	869.5	7.0	3	205
	98.91	861.8	869.2	7.3	4	162
	98.84	851.1	869.3	18.2	1	247
	98.82	860.5	869.2	8.7	3	234
	98.78	856.8	869.1	12.3	3	138
	98.76	858.3	869.1	10.8	3	169
	98.65	858.7	869.0	10.3	2	237
	98.60	860.9	868.9	8.0	3	212
	98.54	862.8	868.5	5.7	4	188
	98.48	861.7	868.2	6.5	4	191
	98.41	862.6	866.5	4.0	8	252
	98.37	861.7	865.3	3.6	5	257
	98.33	860.5	865.1	4.6	3	300
	98.26	857.9	864.8	7.0	3	253
	98.20	858.4	864.5	6.0	4	219
	98.15	855.2	864.3	9.1	3	173
	98.11	852.7	864.3	11.7	2	218
	98.07	853.3	864.3	11.0	2	211
	98.04	853.8	864.2	10.4	2	206
	97.98	854.8	864.1	9.3	3	195
	97.92	855.8	864.1	8.3	2	299
	97.84	858.3	863.8	5.5	4	248
	97.76	858.5	863.1	4.6	4	233
	97.69	858.0	862.2	4.2	5	226

			RIVER DISCHARGE: 3,866 cfs			
Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
	97.62	857.1	861.3	4.2	5	212
	97.54	856.0	860.9	4.9	3	302
	97.46	855.0	860.7	5.6	3	318
	97.33	853.2	860.2	7.0	3	246
	97.26	852.3	859.9	7.6	4	190
	97.17	851.1	859.8	8.7	2	216
	97.08	849.9	859.8	9.9	2	238
	96.98	848.7	859.7	11.0	2	277
	96.89	847.4	859.6	12.2	2	324
	96.80	846.2	859.6	13.4	1	377
	96.70	847.8	859.6	11.8	2	366
	96.61	849.4	859.5	10.1	2	349
	96.52	851.0	859.4	8.4	2	328
	96.43	852.6	859.2	6.6	3	293
	96.33	852.7	858.9	6.2	3	315
	96.24	852.8	858.6	5.8	3	343
	96.15	852.9	858.2	5.3	3	385
	96.05	853.0	857.5	4.5	3	449
	95.96	852.4	856.8	4.4	3	504
	95.91	852.0	856.5	4.5	3	505
	95.87	851.8	856.1	4.3	4	260
	95.84	851.6	855.7	4.1	4	256
	95.80	851.3	855.4	4.1	4	262
	95.75	850.7	854.9	4.2	4	265
Downstream End of Model	95.63	849.5	851.9	2.4	8	221

Attachment D

PRELIMINARY SEDIMENT MODEL RESULTS

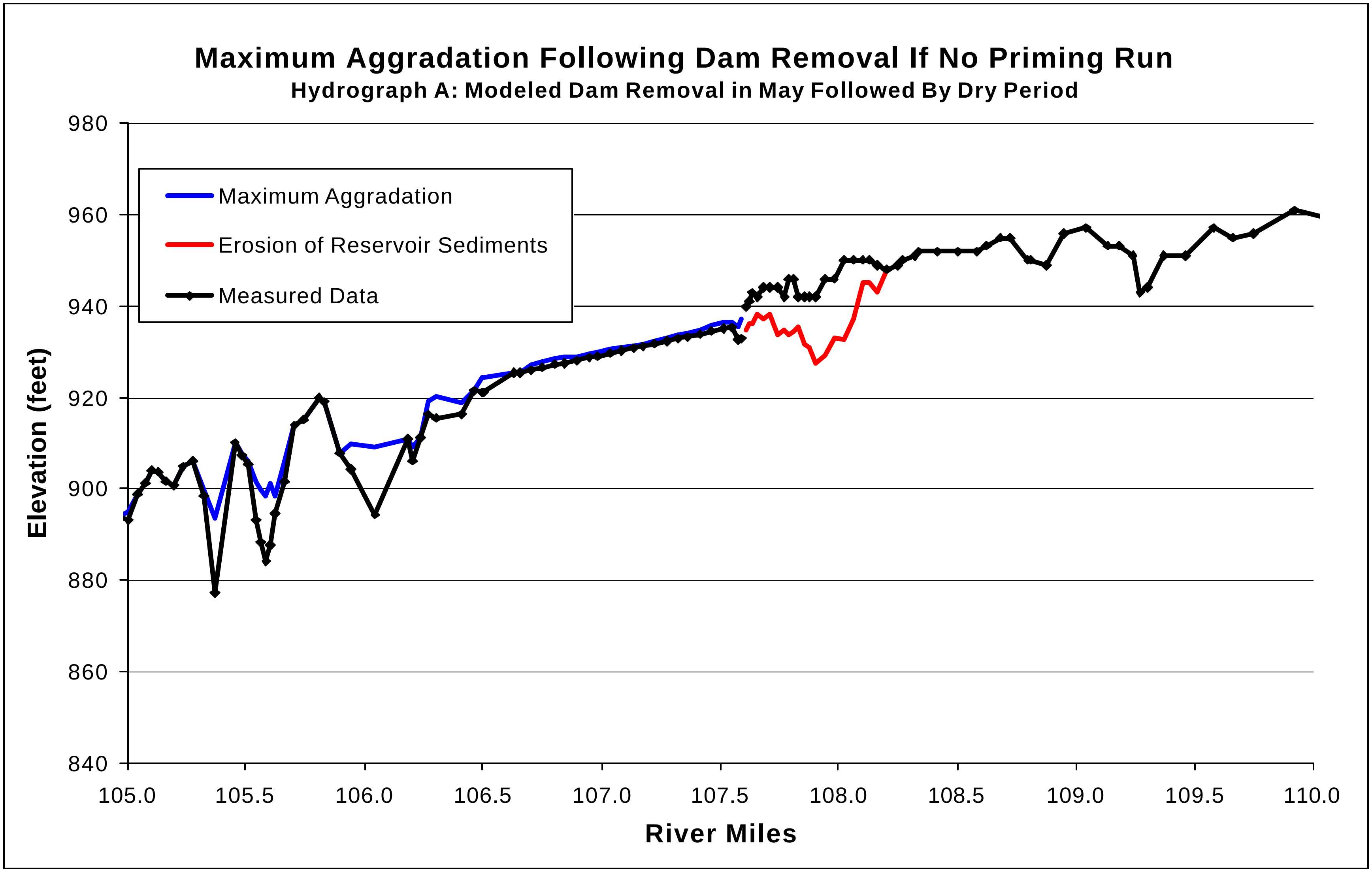


Figure D-1.—Longitudinal profile plot was made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation following the dam removal for the first 5 miles downstream from the dam. The dam removal was initially modeled to occur in May, followed by a dry period (few peak flows). Initial model results showed large amounts of deposition in deep river pools downstream from the dam. However, these results were unlikely because sediment that currently passes through Savage Rapids Reservoir during peak flows would have filled these river pools long ago.

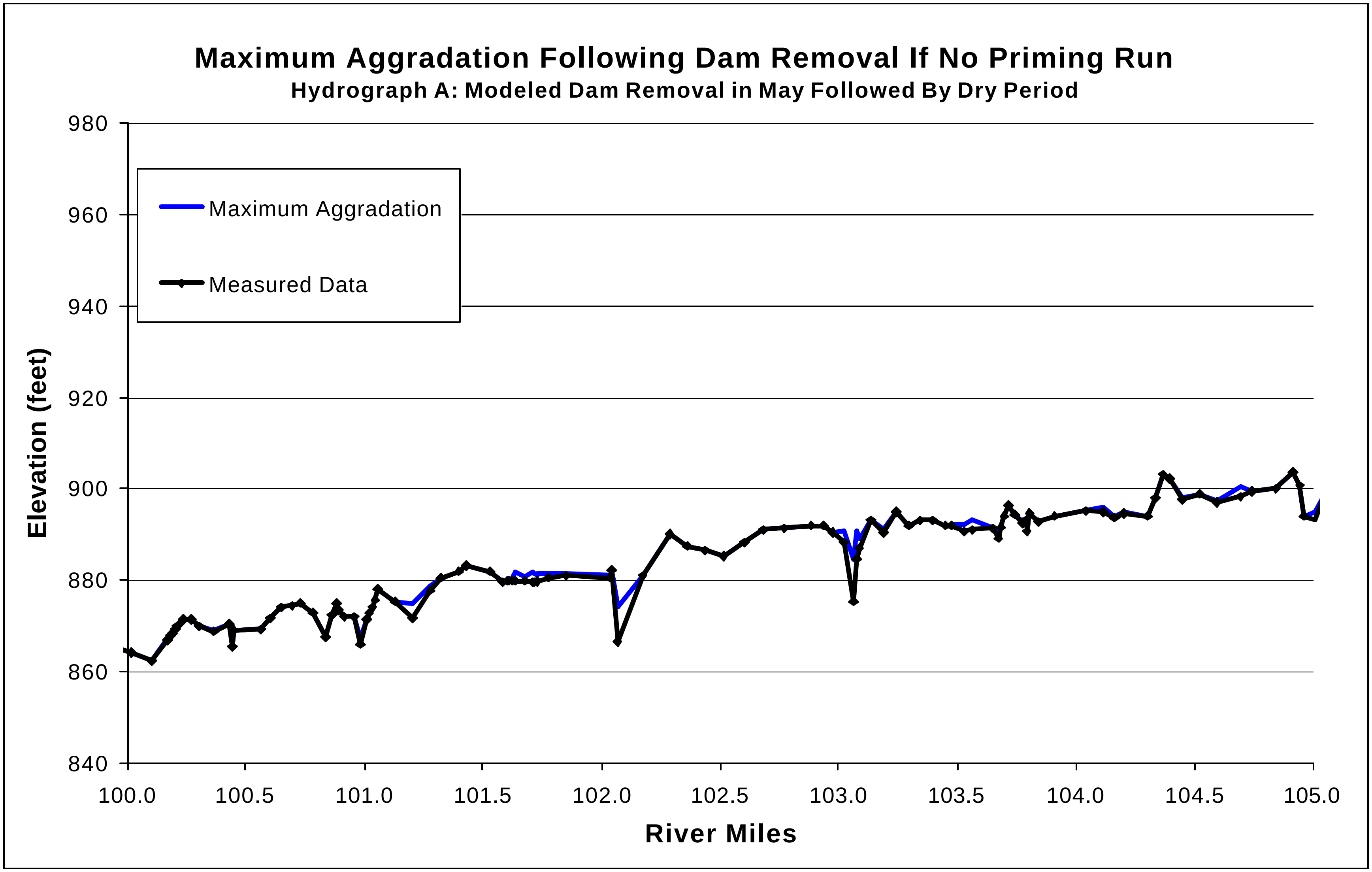


Figure D-2.—A longitudinal profile plot made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation for river miles 100 to 105 (5 to 10 miles downstream from the dam).

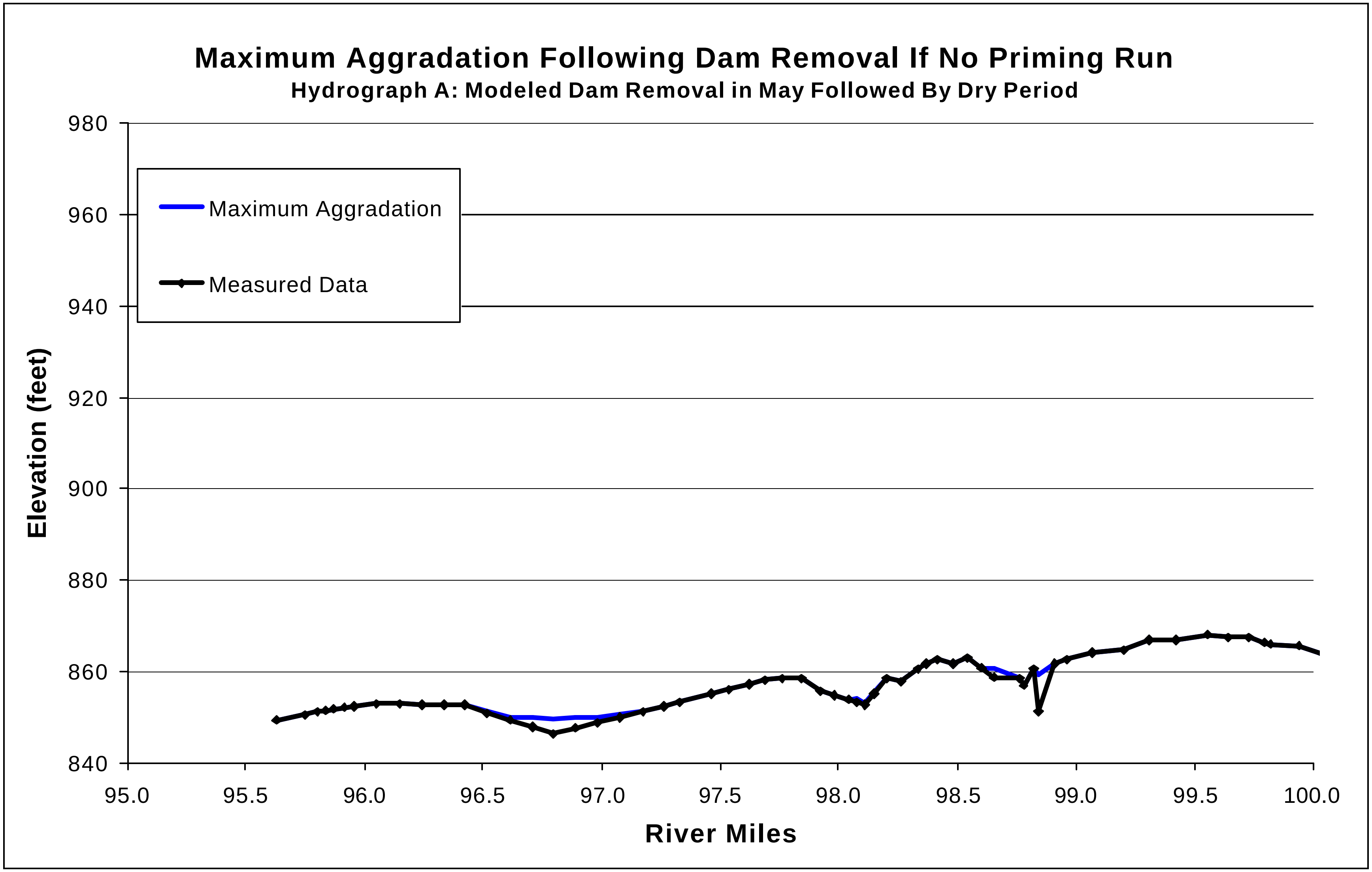


Figure D-3.—A longitudinal profile plot made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation for river miles 95 to 100 (10 to 15 miles downstream from the dam).

Attachment E

SEDIMENT PRIMING RUN RESULTS

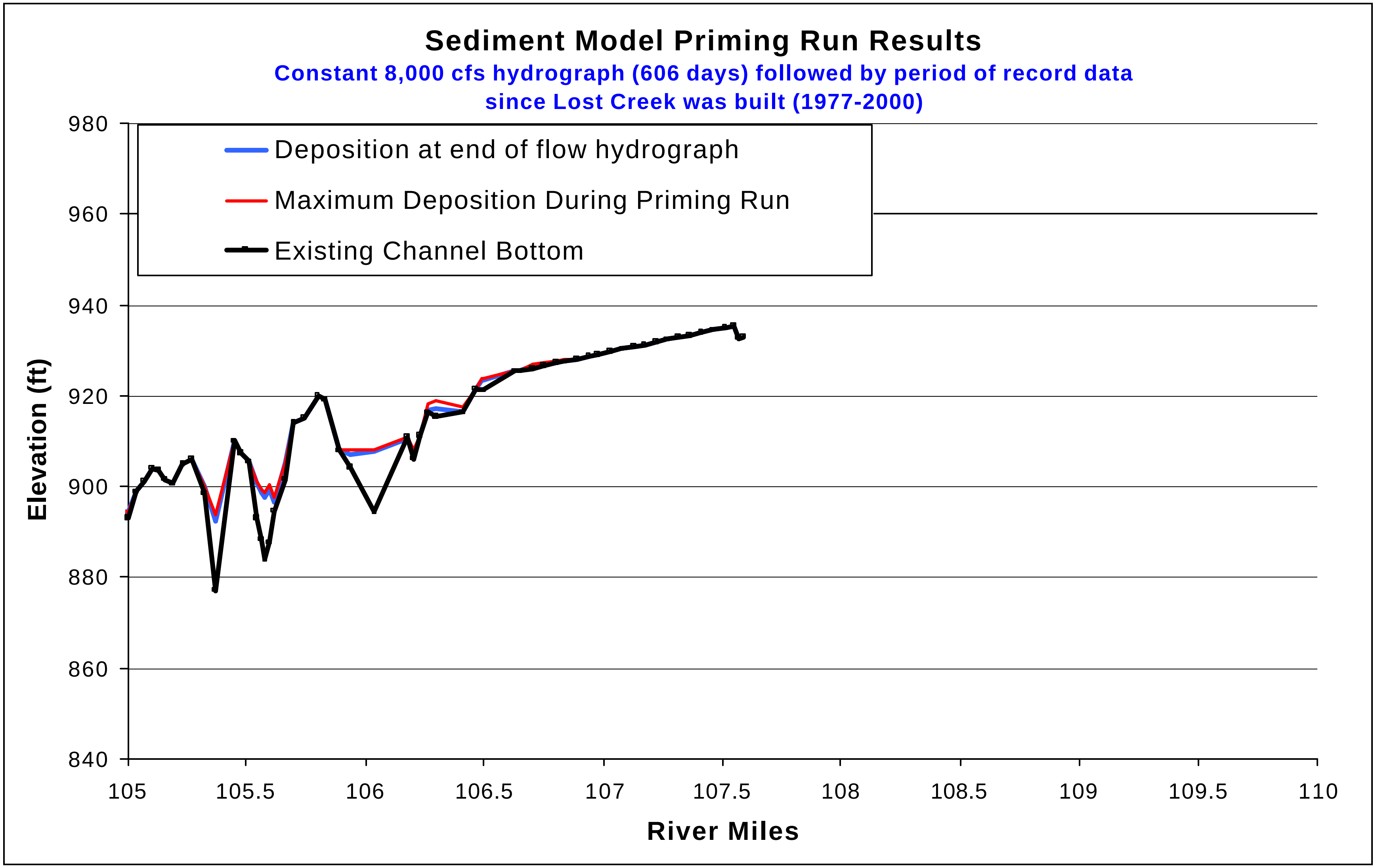


Figure E-1.—Results for sediment model priming run for first 5 miles downstream from Savage Rapids Dam. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

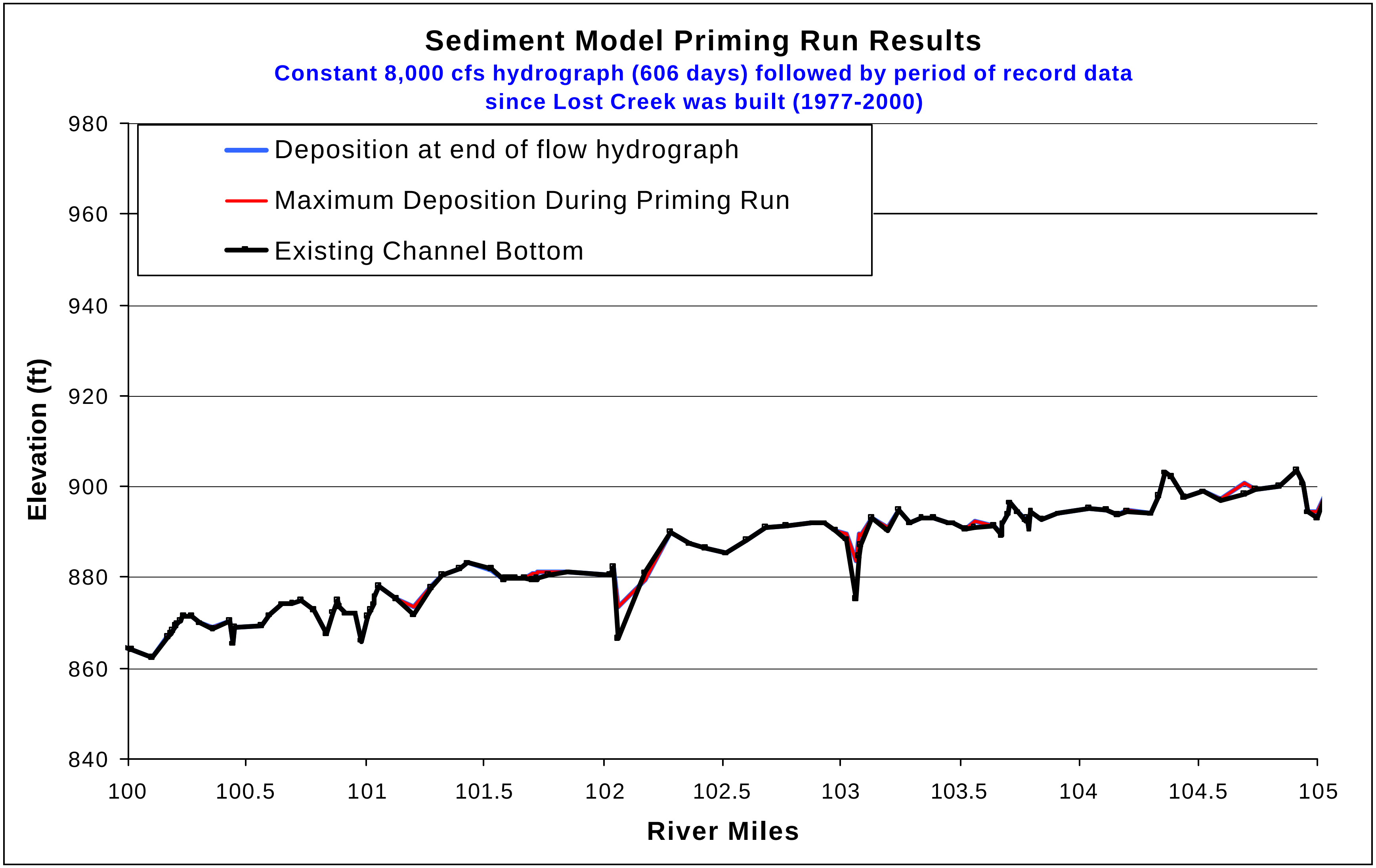


Figure E-2.—Results for sediment model priming run for the second 5 miles downstream from Savage Rapids Dam. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

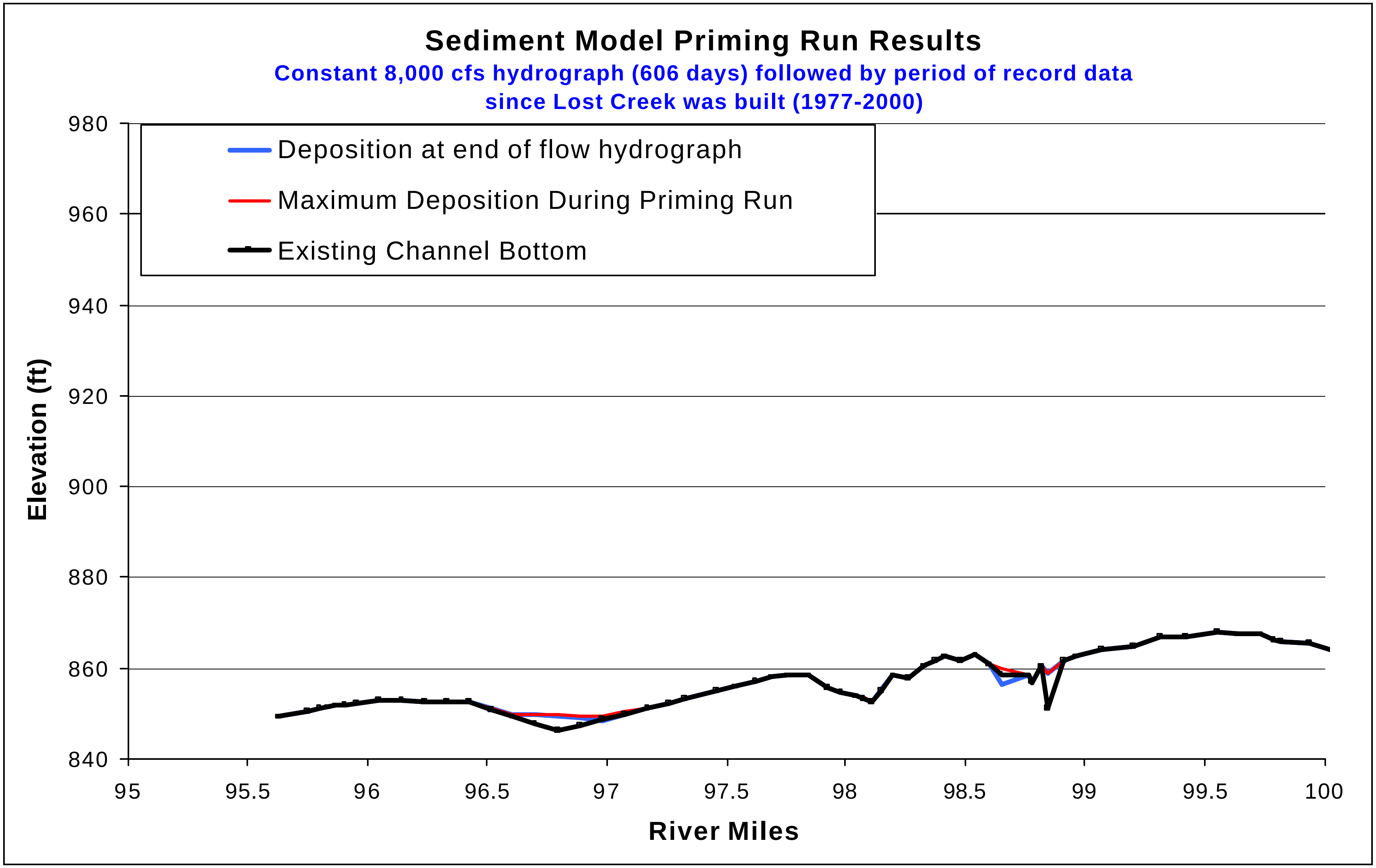


Figure E-3.—Results for sediment model priming run for the 5 miles directly upstream from the confluence with the Applegate River. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

Attachment F

SERIES OF PLOTS ILLUSTRATING SEDIMENT
TRANSPORT DOWNSTREAM FROM THE
DAM SITE FOLLOWING DAM REMOVAL

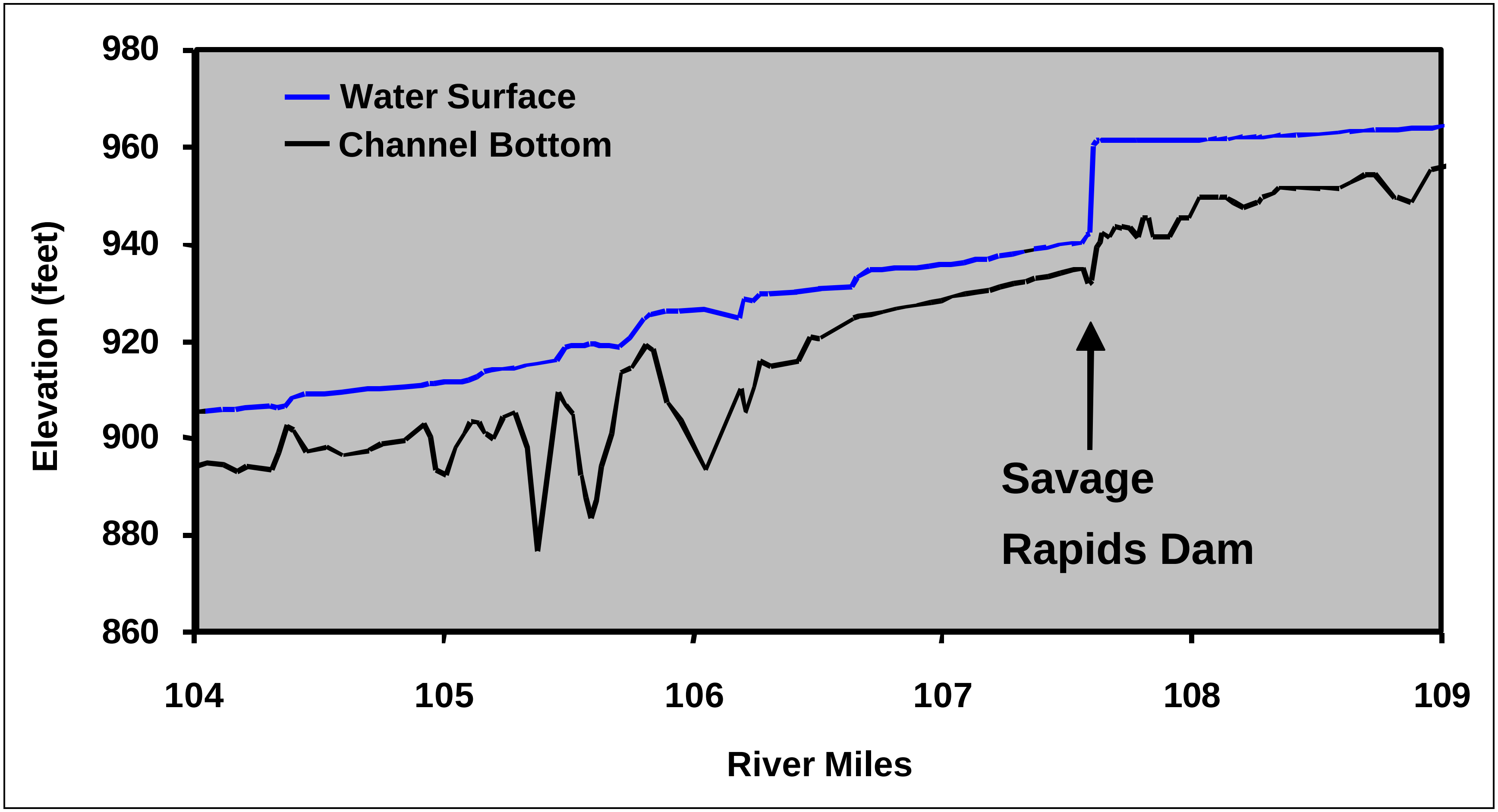
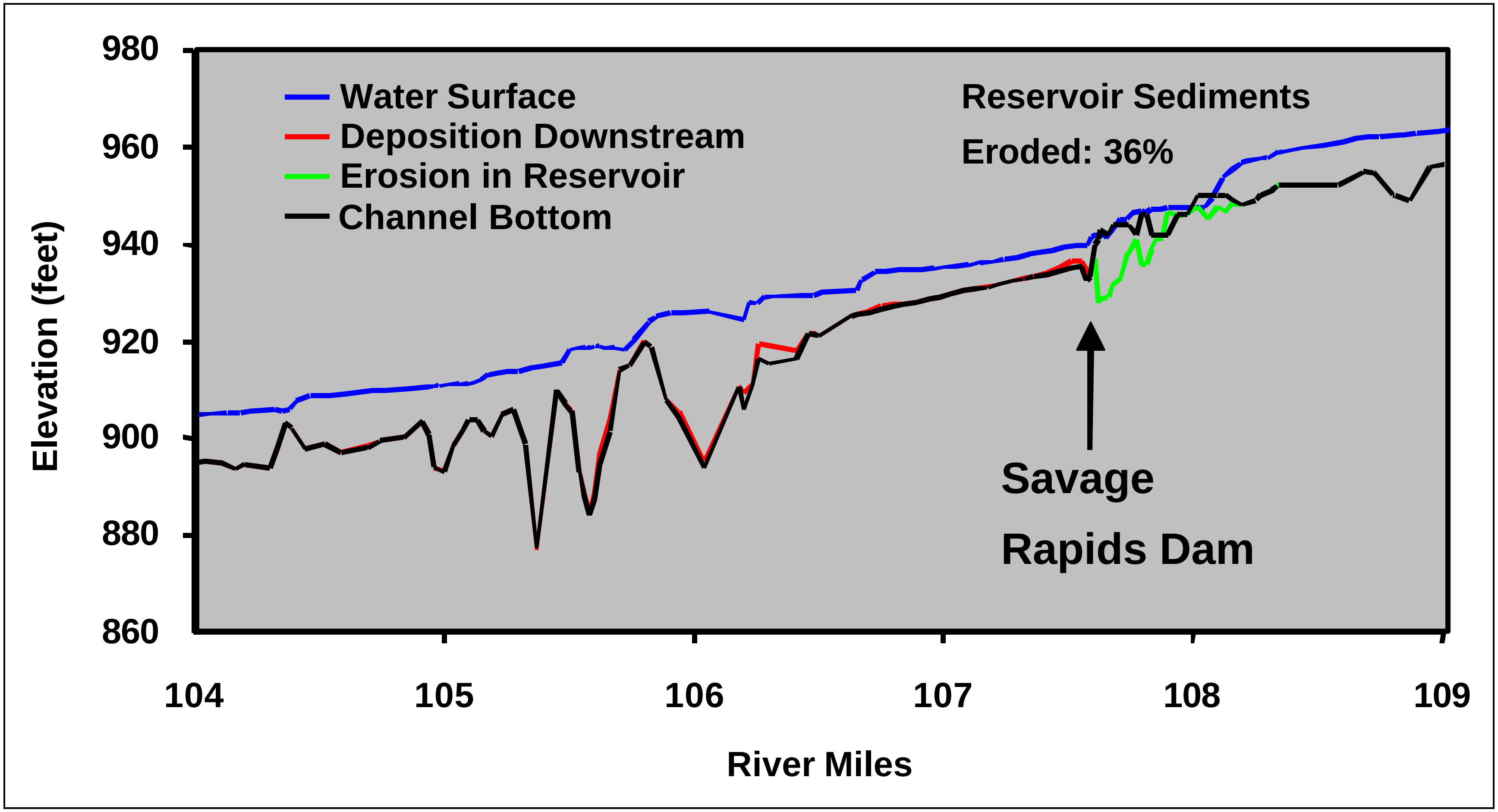


Figure F-1.—An animator was developed of the following slides that represents the model results for erosion of reservoir sediment and subsequent deposition downstream following the removal of Savage Rapids Dam.



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 36%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-2

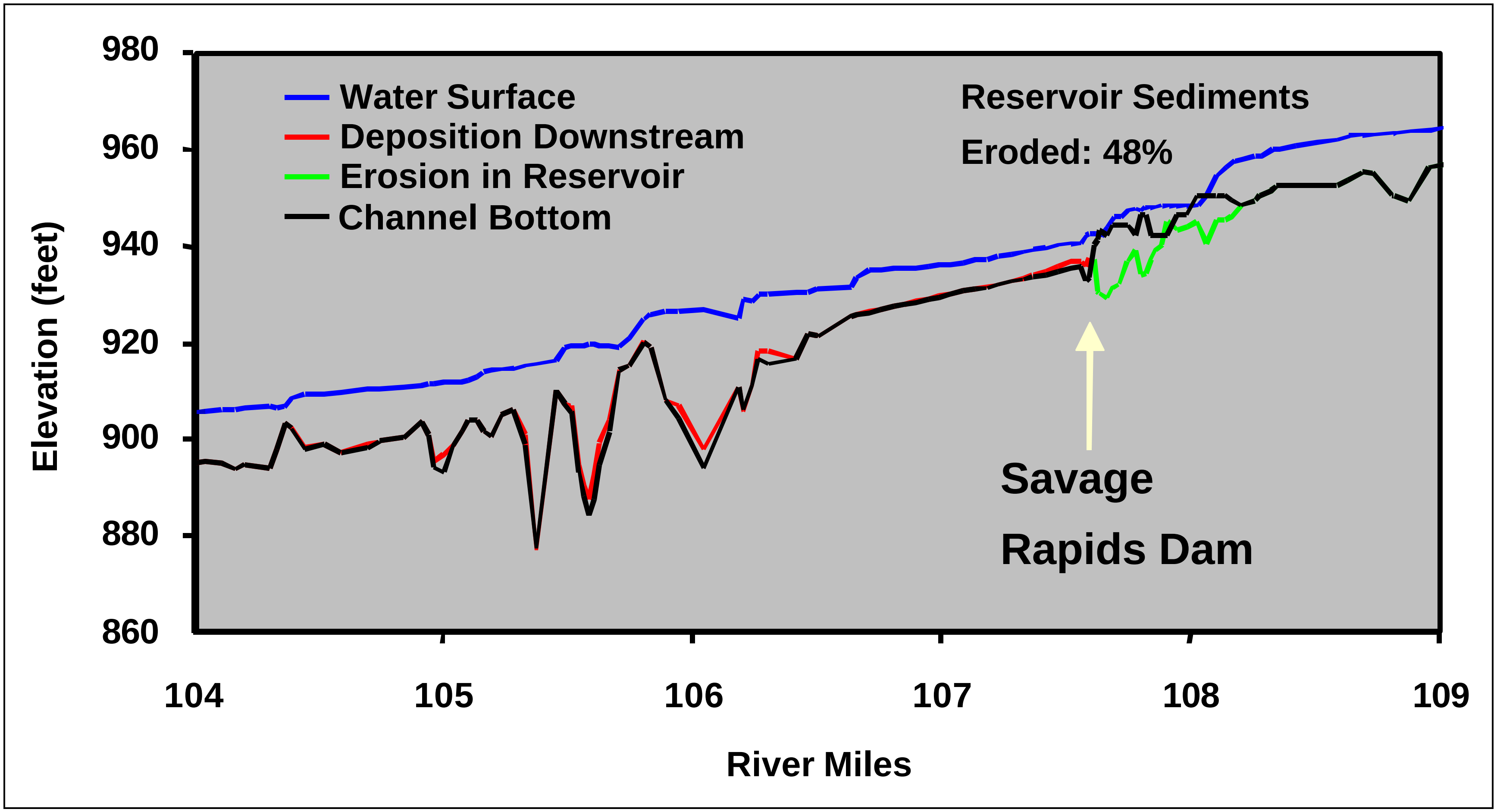
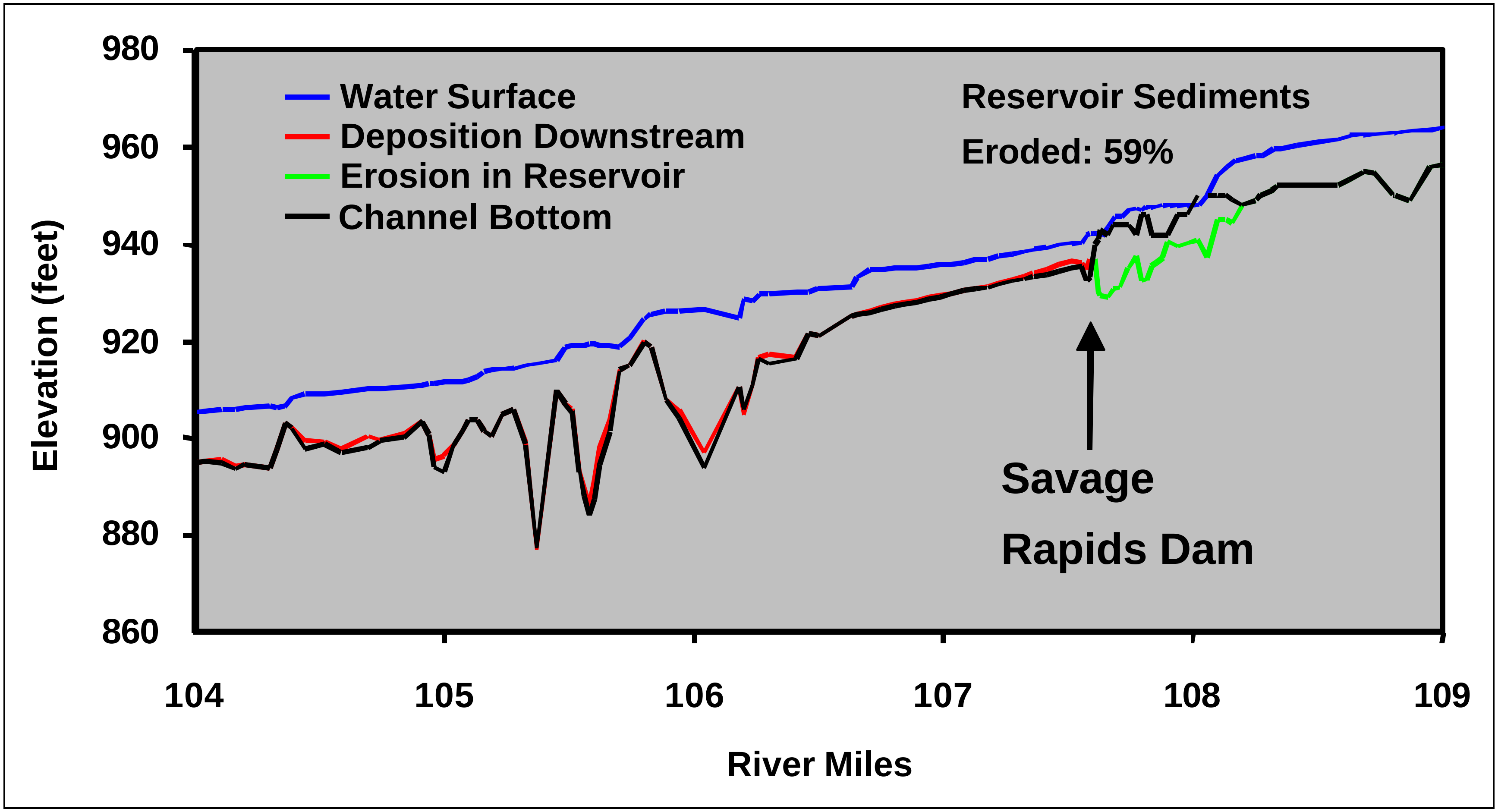

Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 48%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

Figure F-3



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 59%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-4

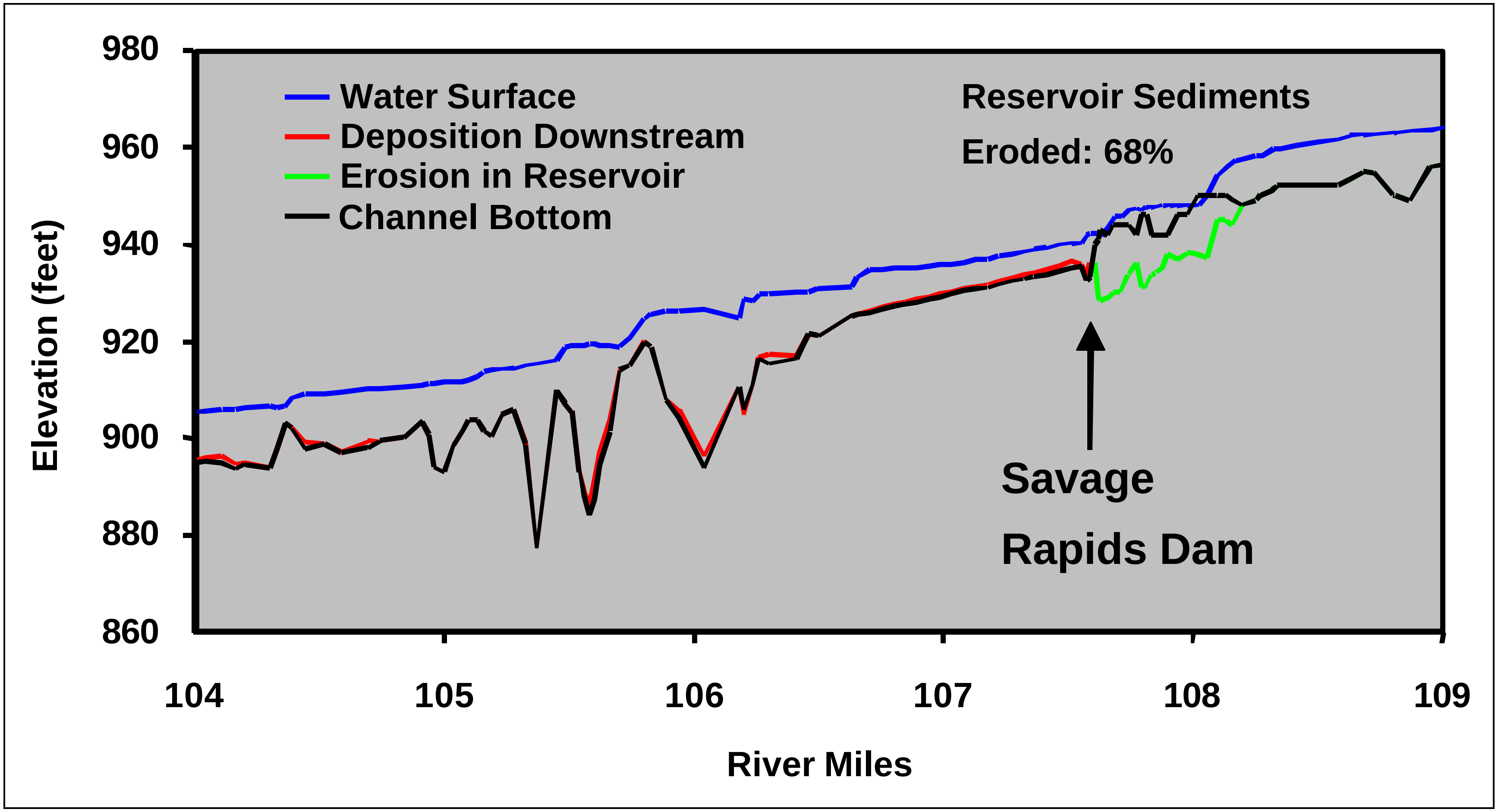
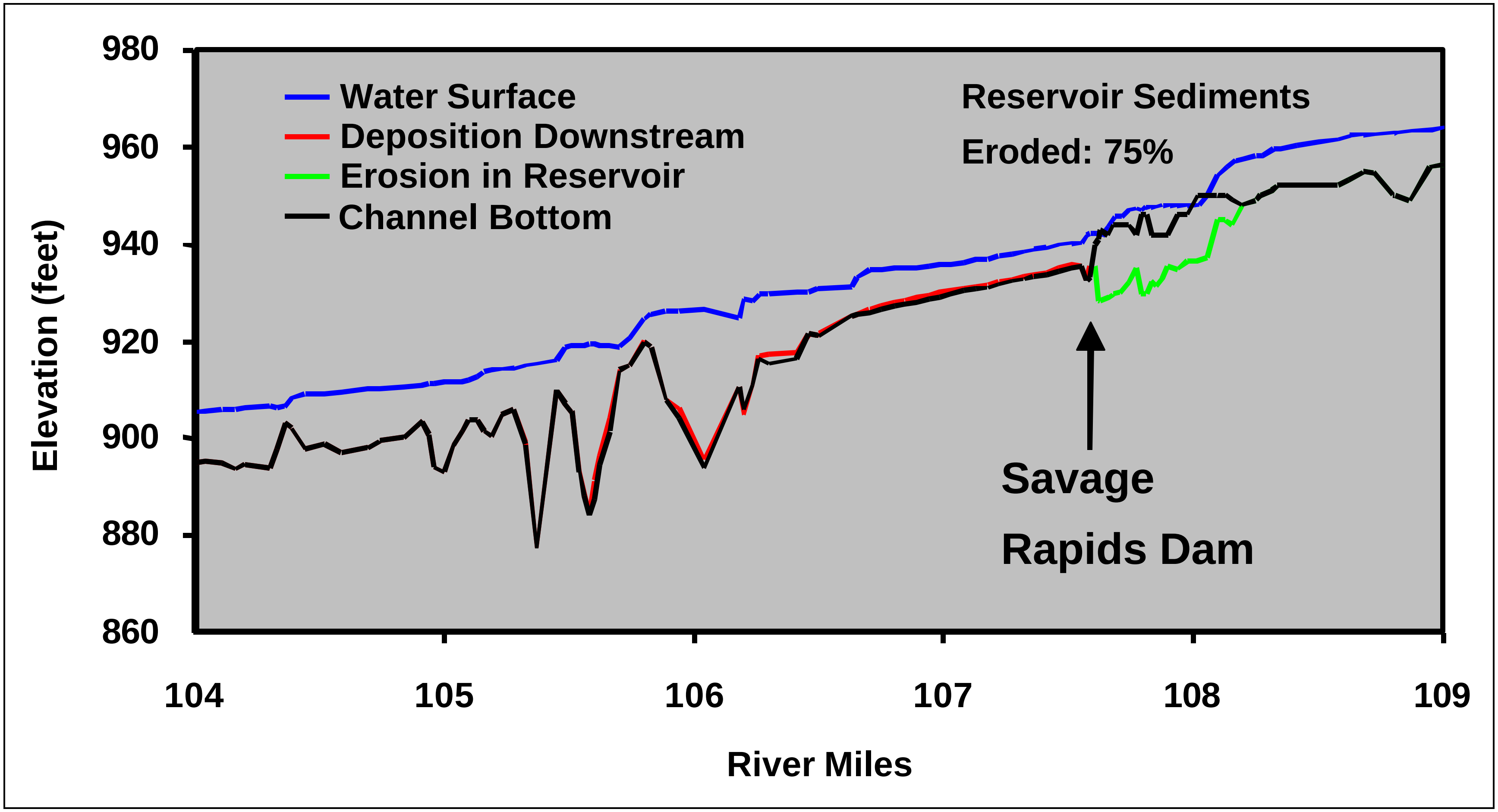
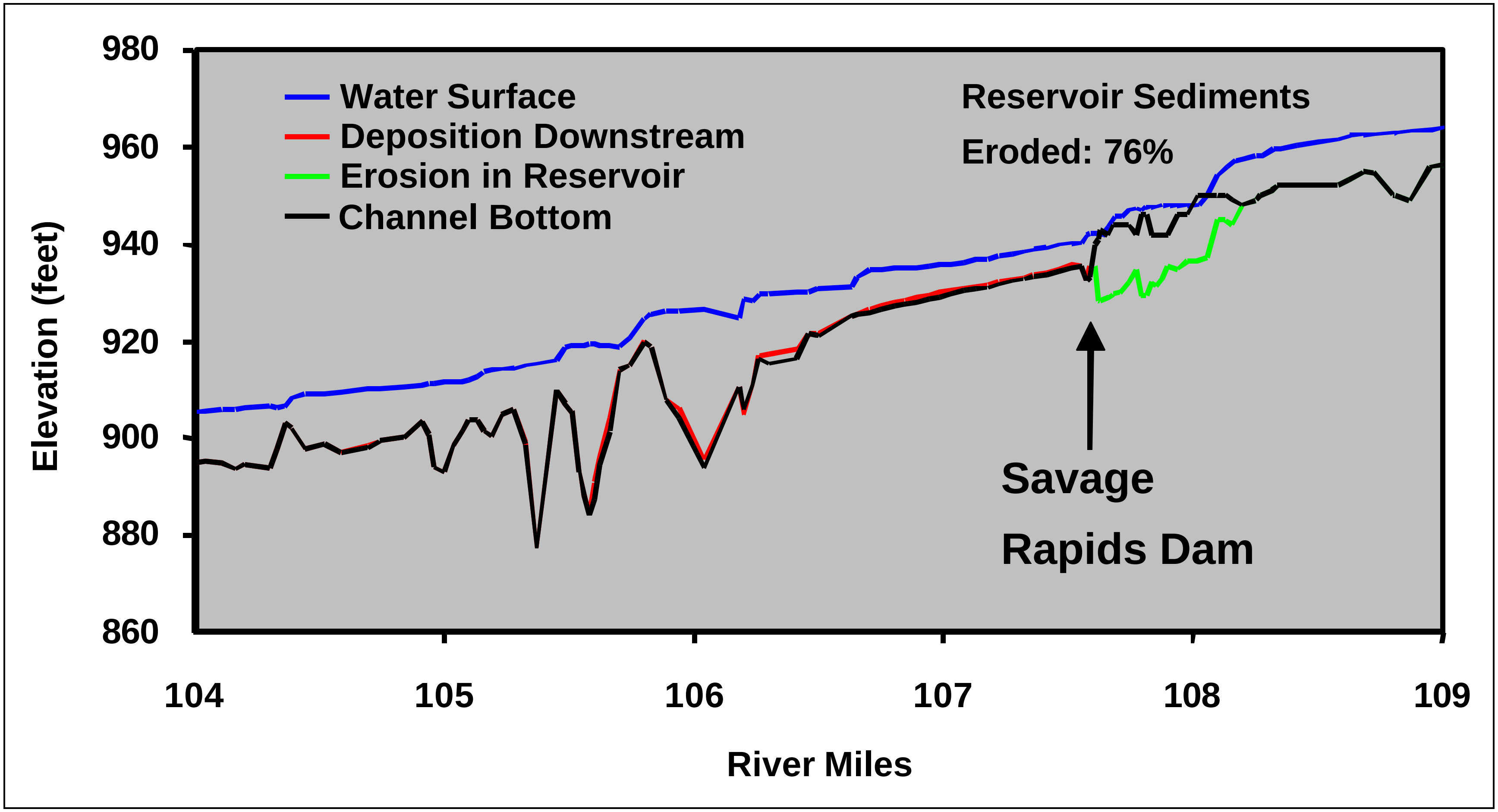

980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 68%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-5



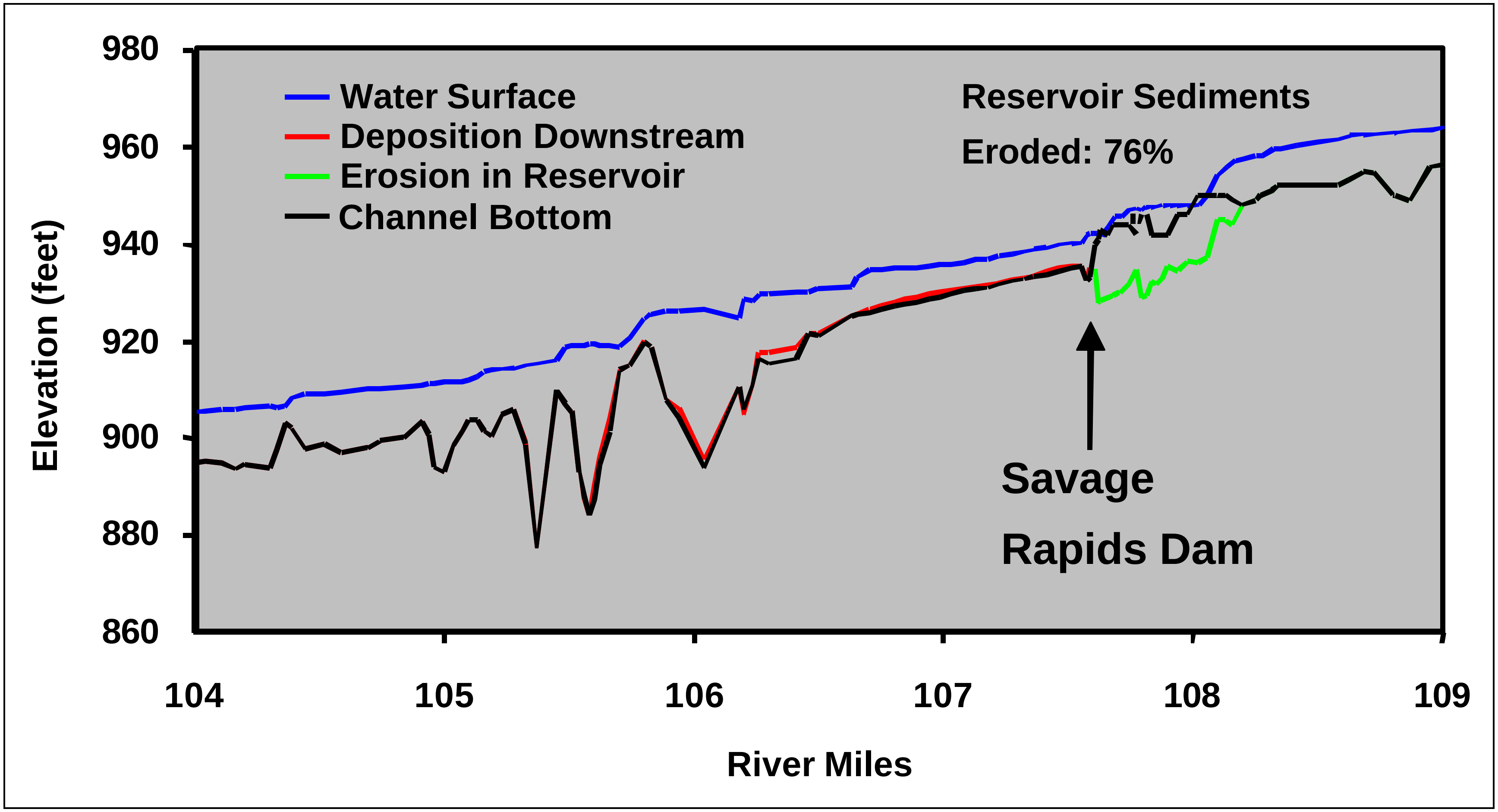
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 75%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

Figure F-6



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 76%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-7



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 76%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

Figure F-8

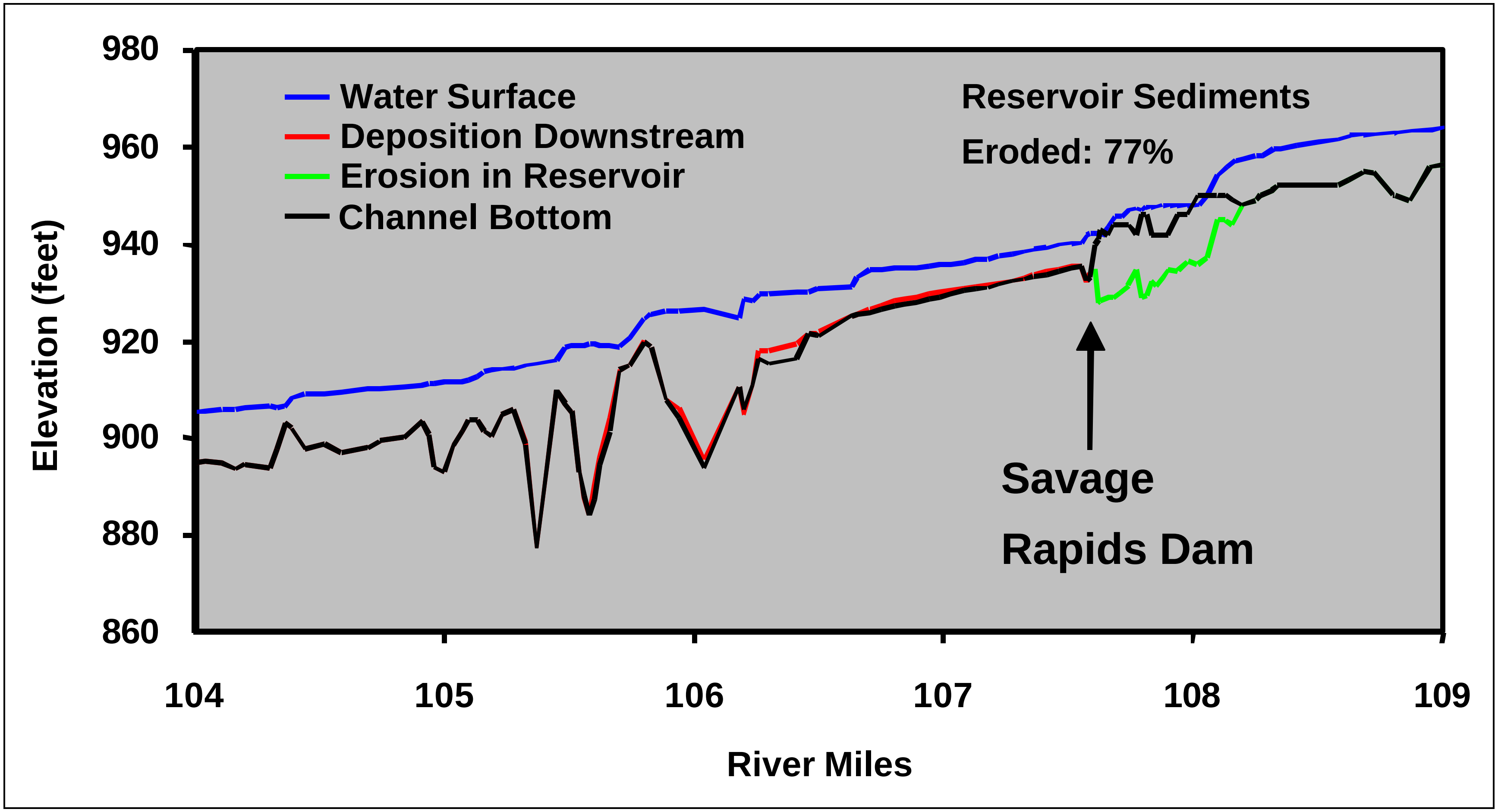
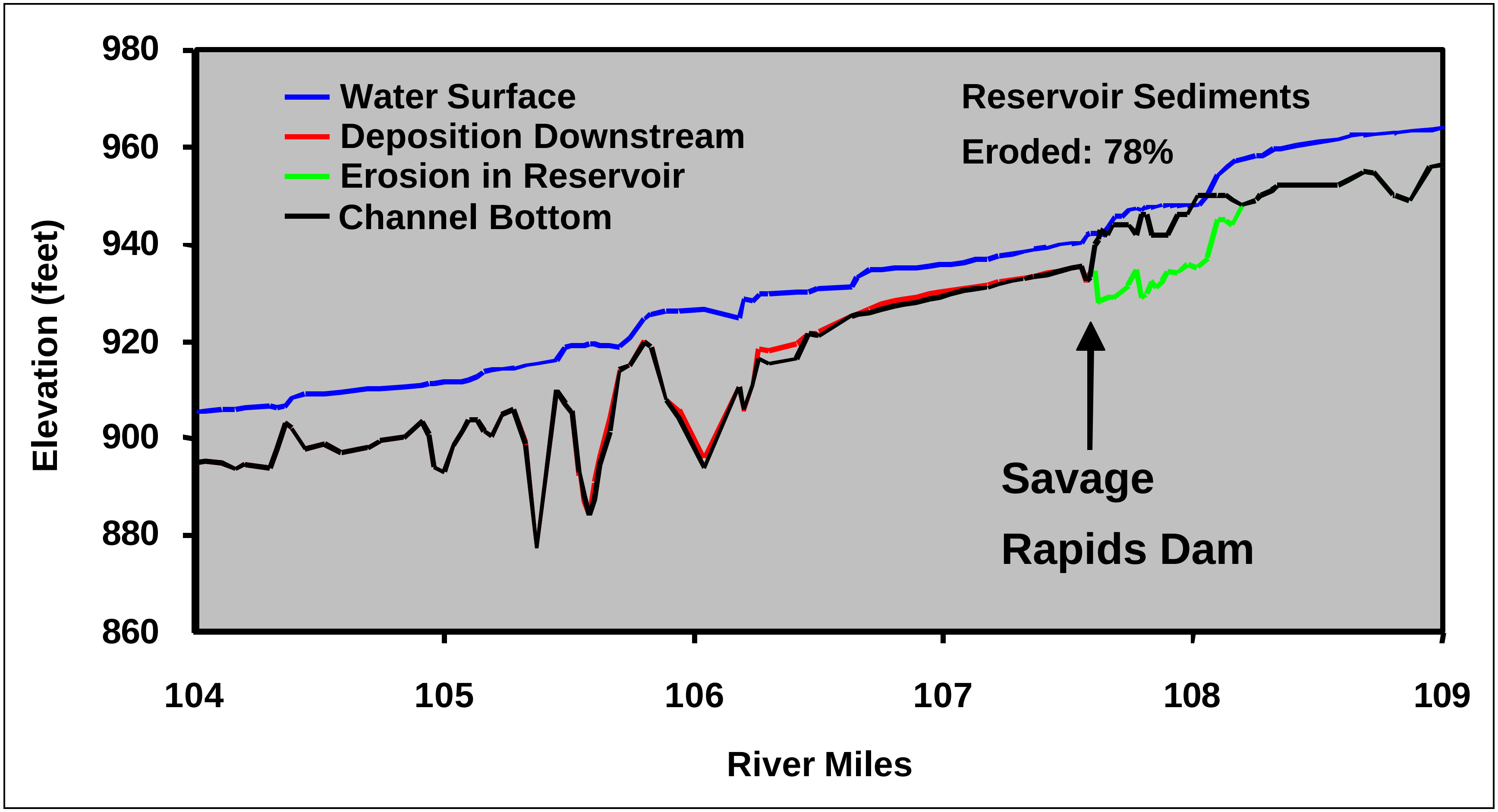
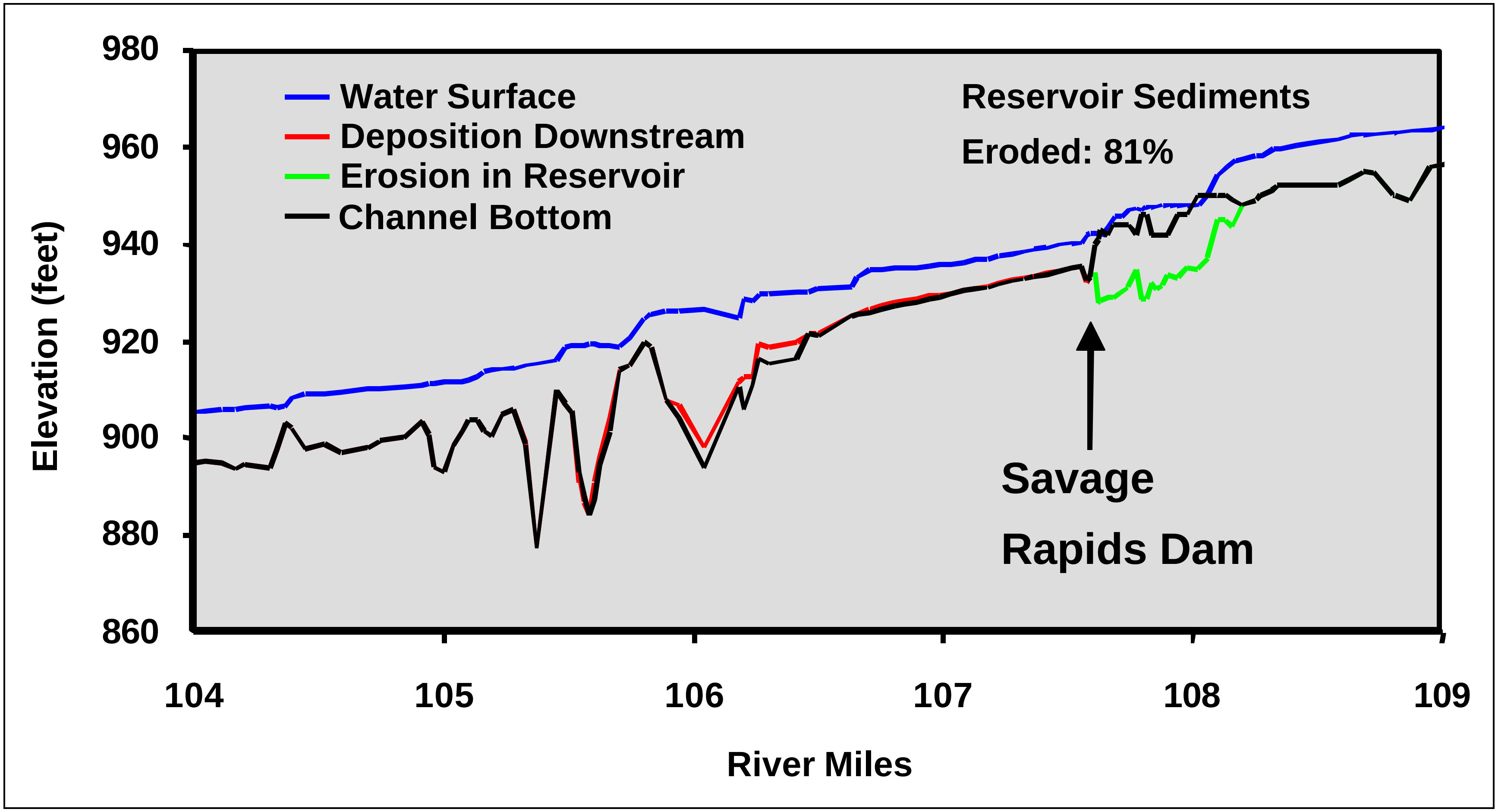

Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 77%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-9



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 78%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-10



980
960
940
920
900
880
860
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 81%
Savage
Rapids Dam
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-11

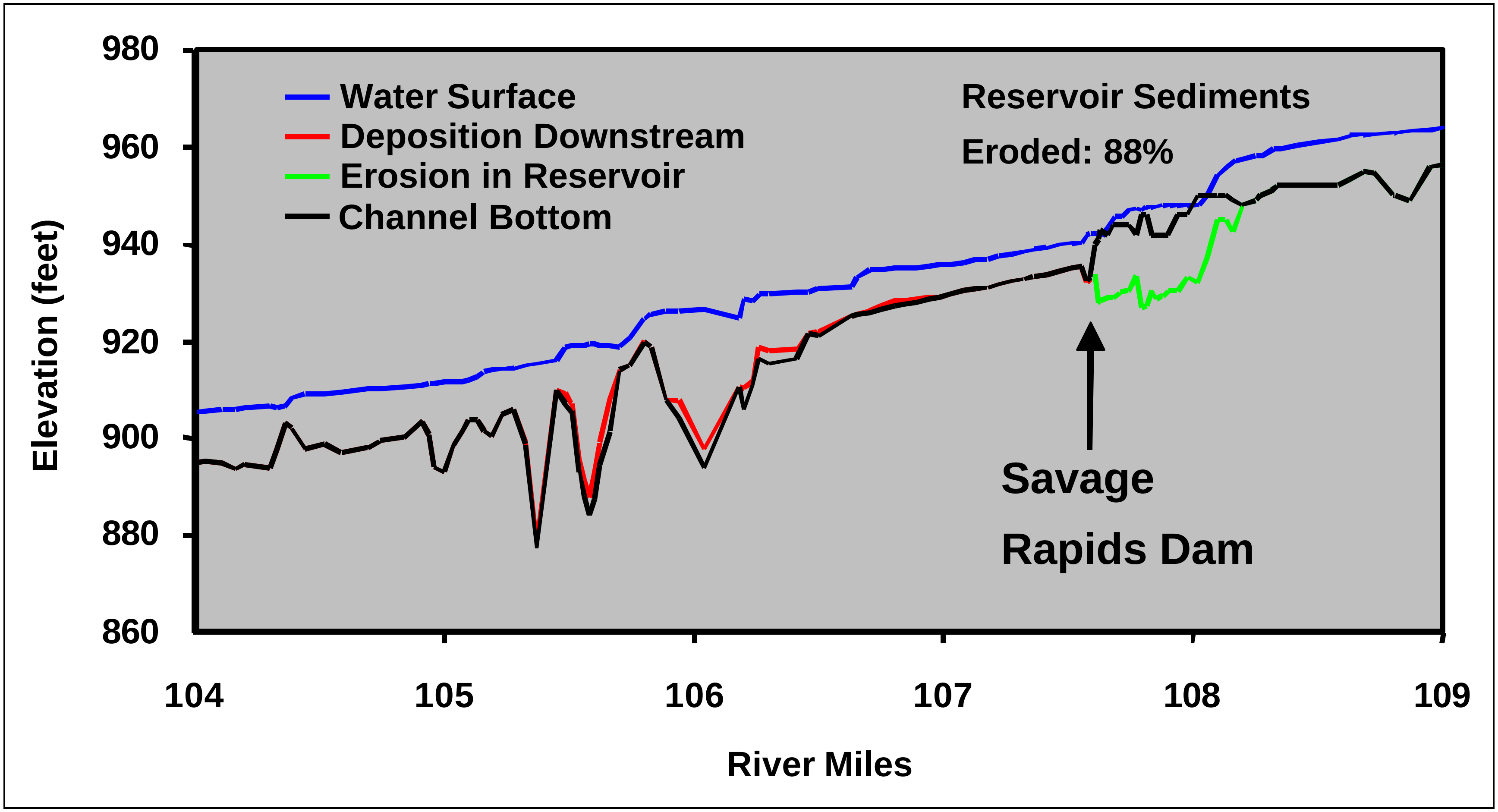
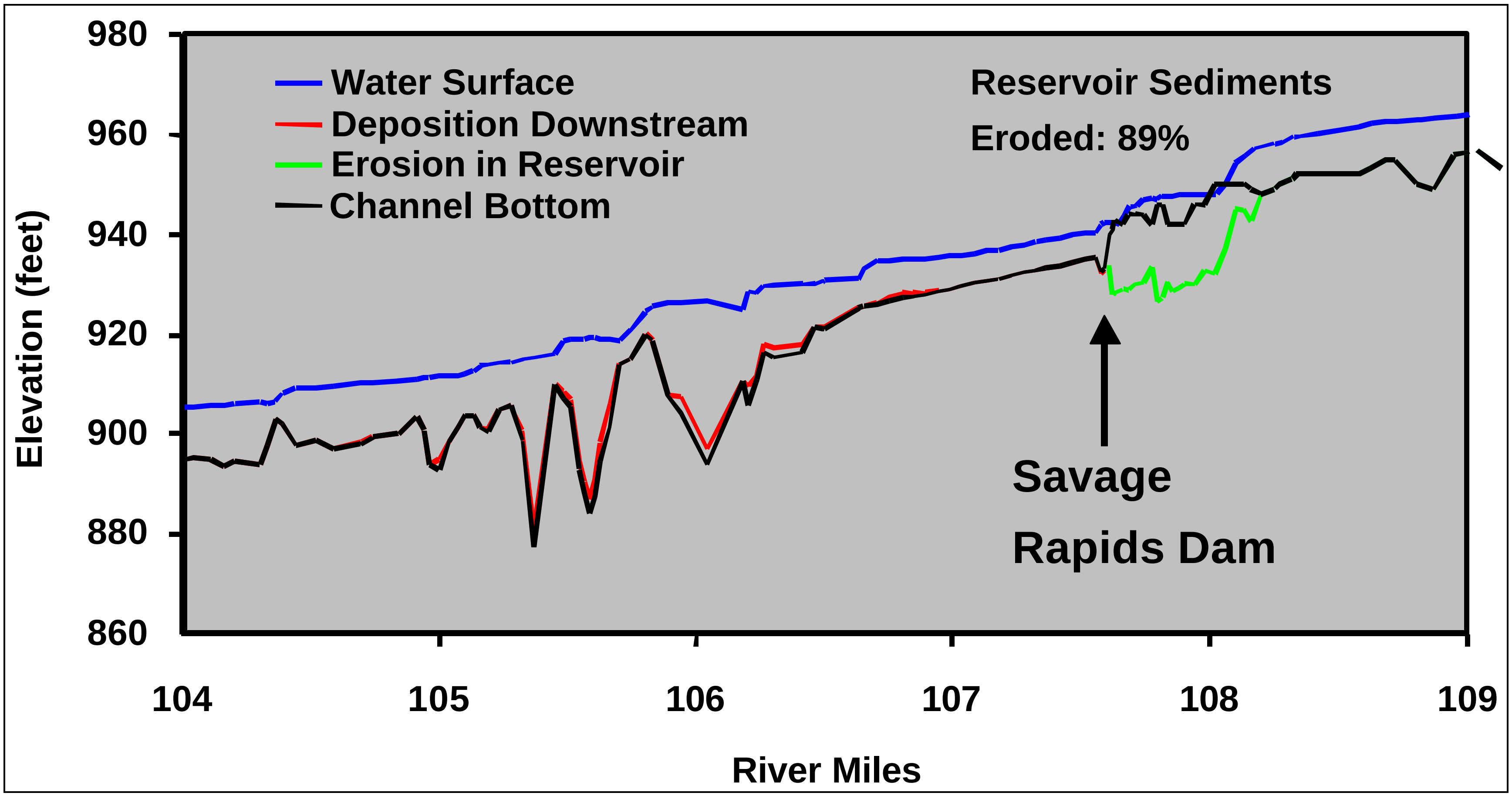

Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 88%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

Figure F-12



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 89%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-13

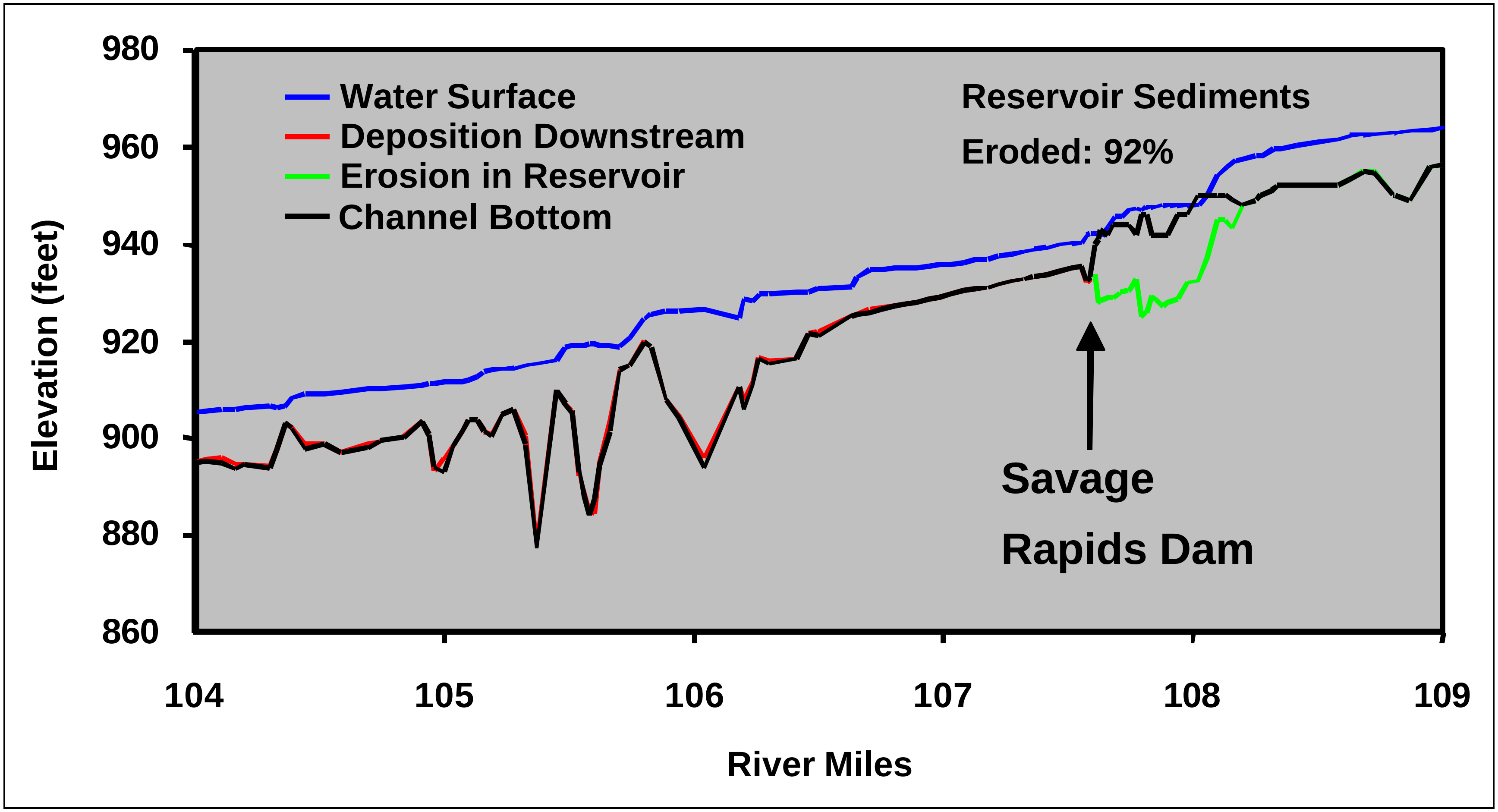

980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 92%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-14